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PREVENTION OF MOLD GROWTH IN INTACT EGGS BY TREATMENT WITH A CATIONIC DETERGENT

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Bacteria and mold spores which contaminate the macroscopically clean shell surface of a hen's egg in the nest and during subsequent handling are responsible for most types of microbial spoilage of stored eggs. Haines (1939), Mallmann and Michael (1940), and Romanoff and Romanoff (1949). Penetration of these microorganisms through the eggshell should be prevented, therefore, both prior to and during storage of shell eggs. Decomposition of egg contents due to growth of bacteria, and especially of molds, is sometimes encountered under the optimum conditions for retardation of purely chemical changes within stored eggs. When eggs are stored in an atmosphere having a high relative humidity, and when moisture is allowed to condense on their shells, physicochemical disintegration of the egg contents is retarded but microbial spoilage is favored.

Three practicable methods can be suggested for preventing simultaneously both chemical and microbial deterioration of stored eggs: 1) strictly fresh eggs may be sealed with chemical agents highly impermeable to water vapor and carbon dioxide and then may be held in a dry, cool atmosphere; 2) they may be coated with an antibiotic substance prior to storage in a cold room which has a high atmospheric content of moisture and carbon dioxide; or 3) they may be treated with both sealing and disinfecting agents, in order to prepare them for most probable survival in their original grade, under the widely variable conditions usually encountered during marketing and storage. Our investigations pertaining to the first method were elaborated in previous publications, Romanoff and Yushok (1948), and Yushok and Romanoff (1949). Our studies applicable to the latter two methods are discussed in this paper.

Growth of molds on the eggshell and within the egg was observed under controlled conditions of high humidity. Prevention of mold growth by a cationic detergent, cetyl pyridinium chloride, was then investigated. The effect of sealing eggs with plastics and with mineral oil, upon incidence of fungal growth, was considered. Finally, cetyl pyridinium chloride was incorporated into various sealing agents, and its fungicidal properties tested.

METHODS AND MATERIALS

Scheibler-type desiccators with a capacity of about seven liters were used as humidifying chambers. In each of several such containers, relative humidity was maintained at 100 per cent by introducing a 100-ml. beaker of distilled water into the closed system. In each of another set of chambers a relative humidity of approximately 98 per cent was estab-

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lished by the inclusion of a beaker of water containing an excess of hydrated calcium sulfate, Lange (1946, p. 1,397), and by the presence of some of this very slightly soluble salt sprinkled on the bottom of the chamber.[2] The temperature, however, was not regulated within the narrow range necessary to prevent the relative humidity from rising to 100 per cent. The occasional condensation of moisture in these chambers fitted into our scheme to use as drastic testing conditions as are ever encountered in practice.

Molds were grown on eggs held for a 20-day period in a humidifier saturated with water vapor. One of these moldy eggs was placed in the lower section of each humidifying chamber to insure an abundant supply of heterogeneous mold spores. A wire screen of one-half-inch mesh was substituted for the desiccator plate on the central platform of each container, in order to present less obstruction to passage of mold spores. The upper section of each humidifier was then divided into four compartments by means of wire screens.

Newly laid eggs with sound shells and no macroscopic surface contamination were selected. Eight eggs were individually immersed in a given treating solution for a two-second period. After they had been allowed to dry on a wire rack, four of these treated eggs were stored in one of the wire compartments of a humidifying chamber completely saturated with moisture; the four remaining eggs were placed in a humidifier in which there was intermittent condensation of moisture. After each container was filled with four sets of treated eggs, it was sealed tightly and held at room temperature [ranging from 21 to 24°C.(70 to 75°F.)].

After a 20-day storage period the eggs were removed from the humidifiers and the extent of external mold growth judged qualitatively, under both visible and ultraviolet light. Observations were made of the fluorescence of the moldy eggshell surface exposed to ultraviolet light filtered through Corning Violet Ultra Glass No. 586 (maximum transmission at 365 mμ.).

Each egg was then candled to detect yolks adhering to the shell and mold pigments in the egg contents. All eggs in which internal mold pigment was not detected were kept at room temperature and room humidity for an additional 20-day period, and again candled. Their contents were then removed and examined for molds.

RESULTS AND DISCUSSION

A. *Mold Growth on Eggs Stored at High Humidities:* Growth of molds on eggshells was first observed five days after eggs had been placed in the humidifying chambers. Some mycelium fragments were green; others were white. Later, red-pigmented colonies developed and in some cases penetrated through the eggshell. After a 20-day period, fungi with light-brown, black, and green aerial parts were predominant. Because widely diverse colony characteristics were observed, it was presumed that many species of fungi were present in each humidifier. However, the practical objectives of this study did not require definite identification of the mold species. A

[2] A constant humidity can be maintained in a closed system at a given temperature by a saturated aqueous solution of a salt over an excess of its solid phase.

thorough investigation of the molds commonly found on eggs has been made by Mallmann and Michael (1940). For purposes of the present work, differentiation by means of fluorescence was deemed sufficient.

Colonies of molds growing on the shell surface showed a very distinctive fluorescence. Under ultraviolet light they appeared bright-red, yellow, orange, light-green, blue, brown, or black. The green-pigmented fungi fluoresced bright-yellow. On the other hand, certain mycelia appeared red under both visible and ultraviolet light. In general, presence of molds could be quite easily detected by their fluorescence, which contrasted quite sharply with that of the eggshell itself.

Some of the molds penetrated through the shell into the egg contents. Green and red vegetative mycelia were found on the shell membrane surrounding the air space. Some black spots were found in the yolks. In all untreated eggs stored for a 20-day period in the humidifiers, yolks had adhered to the shell. In most cases a prolific growth of molds, usually pigmented brown, was located on the exterior of the shell immediately adjacent to the stuck yolk.

When eggs with adhered yolks were stored for an additional 20-day period at room temperature, all of them became badly decomposed and produced a foul odor. These rots were red, black, or mixed.

B. *Inhibition of Mold Growth by Cetyl Pyridinium Chloride:* After an extensive survey of the literature on antibiotic agents, it seemed worth while to consider the applicability of cationic detergents to preservation of shell eggs. The great effectiveness of these compounds as germicides has been demonstrated, Baker, Harrison, and Miller (1941a) and Hotchkiss (1946). Cetyl pyridinium chloride, for example, has a much higher toxicity to pathogenic bacteria than to chick embryos, Green (1944). In high dilution, it kills certain common pathogenic fungi, Quisno and Foster (1946).

Instead of comparing the fungicidal effect of many cationic detergents, it was decided to limit the study to cetyl pyridinium chloride. Our main objective was to investigate various methods of adapting this detergent to the preservation of eggs.

Under optimal conditions for mold growth, none of the eggs treated with a 1:2000 aqueous solution of cetyl pyridinium chloride[3] developed external moldiness or adherence of the yolk to the shell (Table 1). After a second 20-day period of storage at room humidity, no macroscopic internal mold growth was recognized, either when the eggs were candled or when their contents were placed in a dish.

Mold growth was not completely inhibited by the cationic detergent diluted 1:3000 and 1:4000. Surface growth was limited to a few scattered colonies. This incomplete disinfecting action was more apparent in the humidifiers, where a 100-per cent relative humidity was continuously maintained and where water droplets were usually present on the surface of the eggs. It is possible that these droplets coalesced, trickled off the egg surface, and removed some of the water-soluble fungicide.

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[3] The cetyl pyridinium chloride (trade name—Ceepryn) was generously supplied for these tests by the Wm. S. Merrell Company, Cincinnati, Ohio.

Yolks adhered to the shells in a number of eggs treated with high dilutions of cetyl pyridinium chloride. In some eggs, fungi of a brown or green color were sometimes found, both on the inner and outer surface of the eggshell immediately adjacent to the stuck yolk. In other eggs, there was no macroscopic evidence of mold growth in the area of contact between yolk and shell, but rots invariably developed in these eggs upon further storage. Adhesion of the yolk to the shell within a 20-day period was therefore considered to be a presumptive test for incipient internal mold growth.

TABLE 1

Effect of Cetyl Pyridinium Chloride on Mold Growth and Adhesion of Yolks to Shells of Eggs[1]

Cetyl pyridinium Cl[2]	Eggs treated	Adhered yolks	External mold growth
pts. by wt.	*no.*	*no.*	
1:2000	32	0	None
1:3000	16	2	Light
1:4000	16	3	Light
1:5000	16	10	Moderate
Distilled water	8	8	Heavy
Untreated eggs	64	64	Heavy

[1] Eggs held for a 20-day period at room temperature and at relative humidities between 98 and 100 per cent. [2] Dissolved in distilled water.

Since phospholipids and fats inhibit the germicidal action of cationic detergents, Baker, Harrison, and Miller (1941b) and Rahn (1946), the presence of yolk material on the eggshell surface, or even an adhered yolk, may be expected to prevent normal action of cetyl pyridinium chloride. Therefore, in order to maintain for a prolonged period the fungicidal activity of a cationic detergent deposited on an eggshell surface, chemical deterioration of the egg contents should be simultaneously inhibited by means of a carbon dioxide-impermeable coating agent. The combination of sealing and disinfecting agents is most likely to be effective when applied to newly laid eggs which have had a minimum of handling and which display no gross surface contamination.

C. *Development of Molds on Eggs Coated With Plastics:* Extensive growth of fungi was found on eggs coated with unmodified polystyrene. The mycelia were uniformly spread over the shell surface, but were not so abundant as on untreated eggs. Most of the polystyrene-coated eggs developed stuck yolks, as shown by the data (Table 2). In some mold-covered areas the polystyrene film was brittle and could be easily chipped off. Films plasticized with n-butyl stearate supported a heavy growth of molds and permitted penetration of fungi into the eggs. A substantially smaller amount of mold was found when the butyl stearate-plasticized coating contained cetyl pyridinium chloride [which did not measurably affect permeability of the film to water and carbon dioxide, Yushok and Romanoff (1949)].

A coating of unmodified chlorinated rubber allowed moderate growth of fungi. Butyl stearate enhanced mold growth, while dibutyl phthalate decreased it (see data Table 2). Cetyl pyridinium chloride exerted its

mold-inhibiting action in chlorinated rubber films containing either plasticizer. When used with dibutyl phthalate, it totally prevented the occurrence of shell-adhered yolks and subsequent rotting of the egg contents.

TABLE 2

Incidence of Mold Growth and Adhesion of Yolks to Shells of Eggs Coated With Unmodified and Modified Plastics[1]

Plastic[2]	Plasticizer		Cetyl pyridinium Cl[3]	Eggs treated	Adhered yolks	External mold growth
	Type	Concentration by weight				
		pct.	*pct.*	*no.*	*no.*	
Polystyrene	.....	.....	.....	16	13	Extensive
Polystyrene	BS	4.0	.....	16	16	Heavy
Polystyrene	BS	4.0	0.05	16	2	Trace
Chlorinated rubber	.....	.....	.....	16	12	Moderate
Chlorinated rubber	BS	4.0	.....	16	14	Extensive
Chlorinated rubber	BS	4.0	0.05	16	4	Light
Chlorinated rubber	DP	3.3	.....	16	4	Light
Chlorinated rubber	DP	3.3	0.05	16	0	Trace
Polyvinyl acetate	.....	.....	.....	8	4	Extensive
Polyvinyl acetate[4]	.....	.....	.....	8	0	Light
Polyvinyl acetate[4]	.....	.....	0.05	8	0	None

[1] Eggs held for a 20-day period at room temperature and at relative humidities between 98 and 100 per cent. [2] The concentration of each plastic is 10 per cent by weight in ethyl acetate. [3] This cationic detergent is uniformly distributed in a solution containing five per cent ethyl alcohol and 95 per cent ethyl acetate. [4] Ethyl alcohol is used as a solvent, instead of ethyl acetate.

A polyvinyl acetate film laid down from solution in ethyl acetate permitted extensive growth of molds. It is conceivable that the mold spores immobilized between the shell and the film began to sporulate when sufficient moisture penetrated through the somewhat permeable film. Apparently, the hyphae obtained nourishment from the cuticular layer of the shell and then grew both through the eggshell and through the inert plastic film.

When the same type of film was deposited from solution in ethyl alcohol, only scattered colonies of black molds developed on the surface of the plastic and none of the yolks adhered to the shell. Many of the spores on the surface of the eggshell may have been killed by ethyl alcohol. Addition of cetyl pyridinium chloride to polyvinyl acetate, dissolved in ethyl alcohol, completely mold-proofed the resulting film.

Cetyl pyridinium chloride presumably remains immobilized in the plastic film unless it comes in contact with water, in which it is highly soluble. Thus, it becomes soluble and actively fungicidal under precisely the same conditions which favor sporulation of mold spores. It can be expected to remain in the plastic film for a long period unless leached out by prolonged washing with water. A fresh, infertile egg, sealed with a plastic film containing cetyl pyridinium chloride, therefore should be quite capable of withstanding most of the variable adverse conditions encountered during storage.

D. *Growth of Molds on Eggs Treated With Mineral Oil Mixtures:* Eggs dipped in pure mineral oil prior to storage developed mold colonies

that covered the entire surface of their shells, although growth was not so dense as on untreated eggs. Similar results were obtained with large lots of eggs held under practical conditions by Reedman and Hopkins (1942). On the other hand, Rosser (1942) observed more mold growth on oiled eggs than on those not treated. It is possible that these differences in results may be due to the method of handling the oiled eggs and to the degree of air movement. The sticky, oiled shell surface is more likely to collect mold spores than a dry, smooth surface. The chemical purity of the mineral oil is of importance, however. Mold growth is undoubtedly favored by introducing a source of food for fungi into mineral oil. Our tests showed that heavier growths of molds were found on eggs previously dipped in a mineral oil mixture containing stearic and lactic acids, than on eggs dipped in pure mineral oil (Table 3).

TABLE 3

Occurrence of External Mold Growth and Adhesion of Yolks to Shells of Eggs Treated With Mineral Oil Mixtures [1]

Treatment	Eggs treated	Adhered yolks	External mold growth
	no.	*no.*	
Mineral oil, low viscosity	24	21	Extensive
Mineral oil (96)[2], stearic acid (2), lactic acid (2)	16	16	Heavy
Mineral oil (65), ethyl acetate (25), ethanol (10), Ceepryn (1:1000)	16	0	Trace

[1] Eggs held for a 20-day period at room temperature and at relative humidities between 98 and 100 per cent. [2] Parts by weight.

Cetyl pyridinium chloride was uniformly dispersed in mineral oil by forming a ternary mixture consisting of 65 parts (by weight) mineral oil, 25 parts ethyl acetate, and 10 parts ethyl alcohol. A concentration of 0.1 per cent detergent in this oil-solvent mixture effectively prevented external mold growth and adhered yolks.

TABLE 4

Growth of Molds on Eggs Treated With Mixtures Containing Lactic Acid [1]

Substances dissolved in distilled water	Eggs treated	Adhered yolks	External mold growth
	no.	*no.*	
Lactic acid, 10 pct.	8	8	Extra heavy
Lactic acid, 10 pct.; urea, 10 pct.	8	8	Extra heavy
Lactic acid, 10 pct.; boric acid, 3 pct.	8	2	Moderate
Lactic acid, 10 pct.; Aerosol OT,[2] 1 pct.	8	3	Moderate
Lactic acid, 10 pct.; Ceepryn,[3] 0.1 pct.	16	0	None

[1] Eggs held for a 20-day period at room temperature and at relative humidities between 98 and 100 per cent. [2] Trade name of sodium dioctyl sulfosuccinate. [3] Trade name of cetyl pyridinium chloride.

E. *Prevention of Mold Growth on Eggs Treated With Lactic Acid:* Dipping eggs in 10-per cent lactic acid prior to storage effectively decreased the permeability of eggshells to water and carbon dioxide, Romanoff and Yushok (1948), but unfortunately encouraged the growth of molds

(Table 4). Treatment with a lactic acid solution containing 10-per cent urea by weight gave the same results, except for a change in appearance of the flora. When boric acid or sodium dioctyl succinate (an anionic detergent) was added to lactic acid, molds were somewhat inhibited. Fungal growth was completely prevented by including cetyl pyridinium chloride (1:1000) in the lactic acid solution.

CONCLUSIONS

Eggs stored at relative humidities between 98 and 100 per cent and at room temperature develop shell-adhered yolks and heavy external growth of molds within a 20-day period. During further storage, prolific mold growth develops within the eggs. To some extent molds grow on eggs coated with any of the following substances: mineral oil, polystyrene, chlorinated rubber, and polyvinyl acetate.

Dipping eggs in a 0.05 per cent aqueous solution of cetyl pyridinium chloride prior to storage completely prevents development of molds on eggs.

For the most probable prevention of fungal growth for a prolonged storage period, eggs should be mold-proofed as soon as possible after being laid, at the same time a sealing agent should be applied, to prevent future chemical deterioration. Cetyl pyridinium chloride exhibits its fungicidal properties when properly incorporated into a film of polystyrene, chlorinated rubber, polyvinyl acetate, or mineral oil.

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EFFECT OF FREEZING RATE ON MEAT.[1]

APPEARANCE, PALATABILITY, AND VITAMIN CONTENT OF BEEF

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Many conflicting statements have been published relative to the effect of rate of freezing on the quality of many frozen products. Recently, one of the authors (F.A.L.), in collaboration with others, Lee and Gortner (1949), Lee, Gortner, and Whitcombe (1949a), and Lee, Gortner, and Whitcombe (1946), described the effect of freezing rate on peas, snap beans, asparagus, lima beans, corn, spinach, strawberries, raspberries, and peaches. No significant differences were observed that could be attributed to rate of freezing, except in the case of asparagus. This vegetable showed texture differences, but the differences were really significant only when extremes in the rate of freezing (that is, freezing in liquid air versus freezing in an insulated box) were contrasted.

DuBois, Tressler, and Fenton (1940) concluded ". . . the more rapidly meat was frozen, the better was its all-around quality. However, the palatability of the roast which was frozen at the slowest rate was good; when cooked it was tender and juicy and of good flavor."

Taylor (1930, 1931) stated that physico-chemical changes occurring in the frozen condition, rather than puncturing of cell walls by ice crystals, or rupture of cells by expansion during freezing, was the basic explanation of the drip from thawed fish and meat. He added, after speaking about corrective treatment and drip: "If these findings stand confirmed, the advantages of rapid freezing diminish somewhat in importance." However, he noted that as the speed of freezing is diminished, the appearance of the resulting product undergoes a change. The same author noted (about meat): ". . . at very slow speeds there is a marked translucence."

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The work in this report, together with additional material, is included in a thesis submitted to the Graduate School of Cornell University by Albert Pearson, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Birdseye and Fitzgerald (1932) and Brady (1945) pointed out the importance of quick-freezing meat. Brady stated, however: "It is of interest to note, however, that the palatability committee scores were not significantly different for either method of freezing. . . ." (Slow-frozen versus quick-frozen.)

Hankins and Hiner (1940) concluded that freezing steaks at —7, —23, and —40°C.(20, —10, and —40°F.) materially increased their tenderness over that of unfrozen steaks; also that —23 and —40°C. had significantly more tenderizing effect than —7°C. There was no real difference in effect between the two lowest temperatures. They were tested for tenderness by means of the Warner-Bratzler shear.

Tressler, Birdseye, and Murray (1932) stated that quick-freezing of meat and subsequent storage of the frozen product effects a marked tenderizing of beef. The tenderizing of quick-frozen meat continues during frozen storage.

Smorodintsev (1943) found that meat proteins are not cleaved or denatured by the freezing process. He studied chemical changes taking place in the preservation and defrosting of frozen meat and concluded that the changes were caused by enzymic action. Glucose progressively decreases, while lactic acid accumulates. In stored quick-frozen meat the changes occur more intensively than in slow-frozen meat.

Golovkin (1939) found that in meat frozen by the accelerated process, formation of lactic acid during storage is smaller than in meat frozen by the standard process, rapid cooling retarding decomposition of glycogen.

Ramsbottom and Koonz (1939) found more drip from slowly frozen small steaks than from similar steaks frozen rapidly. However, regardless of rate of freezing, the histological appearance of the defrosted muscle tissue was quite similar to that of unfrozen muscle tissue.

The present study was undertaken to determine whether or not rate of freezing would have any effect on the B-vitamin content of beef, as well as noticeable effect on appearance, color, texture, and palatability of the several samples after cooking.

PREPARATION OF SAMPLE

The wholesale rib cuts and the adjacent six inches of short loin were removed from each of two carcasses after aging six days. The *longissimus dorsi* muscle was stripped out and cut into 14 steaks from each side. All steaks from the right side of the carcass were numbered one to 14, from anterior to posterior. Corresponding steaks from the left side were numbered in the same fashion, except that the letter A was suffixed to each number.

All steaks were wrapped in 300 MSAT 87 Cellophane, with the drugstore wrap, then given an additional wrap in ordinary butcher paper, and labeled.

RATES OF FREEZING

The steaks were divided into three lots, and frozen as follows:

By plate contact at —46°C.(—50°F.). Freezing time: one and one-half hours.

In a home freezer at —18°C.(0°F.) with still air. Freezing time: seven hours.

In an insulated box in a home freezer at 0°F. with still air. Freezing time: 24 hours.

These freezing times were determined by use of thermocouples placed in the center of test samples, and the time required to reach 0°F. was ascertained.

STORAGE

Immediately after freezing, samples of each lot with the A suffix were thawed and broiled to an internal temperature of 66°C.(150°F.). Also, an unfrozen control, which had been held in the refrigerator at 1°C. (34°F.) was cooked in the same fashion. These samples, together with the raw, unfrozen control (held at 34°F.) and the raw, frozen sample from each series, were analyzed for total solids, ether extract, thiamine, riboflavin, and niacin. Because laboratory facilities were not available for pantothenic acid and pyridoxine at the beginning of the project, analyses for these two vitamins were included after the project started. Complete sets were held at 0°F. for analysis after storage for six- and 10-month periods.

ANALYTICAL METHODS

Samples were prepared for analysis by first removing as much fat as possible. One hundred gm. of meat was mixed with 200 gm. distilled water and thoroughly ground in the Waring blendor. Samples of this slurry were used for analyses. Total solids were determined by drying in the vacuum oven at 70°C.(158°F.) for 48 hours, followed by cooling and weighing. The light aluminum dishes containing the dried solid material were crumpled, and placed in the Soxhlet extractors. Anhydrous ethyl ether was used to extract them overnight. After this the samples were removed from the extractors, ground to a powder, and returned for further extraction with anhydrous ethyl ether. After a total of 48 hours, flasks containing the extracted matter were removed, excess ether distilled off, and the samples dried and weighed in the usual fashion. The grinding step in the middle of the extraction was found to give more satisfactory results. Solids are reported on the moisture-free, fat-free basis. Thiamine was determined by the thiochrome method, Moyer and Tressler (1942), and riboflavin by the chemical method of Scott *et al.* (1946). Samples of the slurry obtained from mixing the meat in the Waring blendor were acidified with $1N \cdot H_2SO_4$ in the proportion of 150 ml. acid to 10 gm. slurry. After autoclaving at 15 lb. for 20 minutes, the mixture was filtered, an aliquot of the filtrate adjusted to pH 6.8, and diluted for determination of the niacin. Samples of the slurry were prepared for determination of pantothenic acid by autoclaving in water, and for pyridoxine by autoclaving with $0.055\ N \cdot H_2SO_4$ [Johnson, 1948)]. Niacin was assayed using a culture of *Lactobacillus arabinosus* 17-5, according to the method of Snell and Wright (1941), as modified by Krehl, Strong, and Elvehjem (1943), and Barton-Wright (1944). Pantothenic acid was assayed using a culture of *L. arabinosus* 17-5, according to the method of Skeggs and Wright (1944). Pyridoxine was assayed, using a culture of *Neurospora sitophila*

299, according to the method of Stokes, Larsen, Woodward, and Foster (1943), as modified by Barton-Wright (1945).

Check determinations were run by mixing known weights of ground meat with anhydrous sodium sulfate (two to one) and placing in a vacuum desiccator over sulfuric acid for 24 hours. The mixture was then Soxhlet-extracted eight hours with low-boiling petroleum ether. The extracted residue was dried, weighed, and ground in a Micro-Wiley Mill. A one-gm. sample of the powder was mixed with 100 ml. of 1N sulfuric acid for niacin. As described before, water was used for pantothenic acid, and 0.055 $N \cdot H_2SO_4$ was used for pyridoxine. The mixtures were autoclaved. The solutions were assayed for niacin, pantothenic acid, and pyridoxine by methods given earlier in this article. Lyophilized cultures, Volz and Gortner (1948), rehydrated with sterile saline, were used as inoculum in part of the niacin assays for additional check tests. Results obtained by either method of pre-treatment of sample showed satisfactory agreement.

RESULTS

Palatability[3]*:* Results of the palatability tests (given Table 1) show few differences in the several factors that make up this test. Differences in the figures shown in this table are not great enough to be of any significance. One might suggest that differences in tenderness obtained with mechanical devices, as reported in the literature, may be of academic rather than of practical importance.

TABLE 1

Effect of Rate of Freezing on Palatability of Beef Steaks[1, 4]

Factor		First steer[5]			Second steer[6]		
		−18°C. (0°F.) Insulated	−18°C. (0°F.) Still air	−46°C. (−50°F.)	−18°C. (0°F.) Insulated	−18°C. (0°F.) Still air	−46°C. (−50°F.)
Aroma	I[2]	5.5	5.5	5.6	5.1	4.9	5.5
	D	5.9	6.2	6.1	5.6	5.9	6.1
Texture	I	5.8	5.8	5.2	5.6	5.8	5.7
Flavor of lean	I	5.5	5.6	5.3	5.4	5.6	6.0
	D	5.8	6.4	6.0	5.8	6.1	6.1
Tenderness	I	5.6	5.9	6.4	5.6	5.7	5.9
Juiciness	I	5.4	5.4	4.6	4.4	5.4	5.8
	D	6.0	5.8	5.4	5.0	5.8	6.1
Average		5.7	5.8	5.6	5.3	5.7	5.9
Appearance only[2]		4.5	4.3	4.2	4.3	3.9	4.0

[1] Scores based on seven to one in order of decreasing desirability. Two steaks were scored by each judge for each rate of freezing. [2] Determined on only one steak at each rate. [3] I = Intensity, D = Desirability. [4] Broiled to a center temperature of 66°C.(150°F.) before serving. [5] Six judges. [6] Four judges.

Vitamin Content: Results of the vitamin determinations are shown (Tables 2 and 3; Table 2 shows results of 10 months' storage and Table 3 results of six months on the fat-free dry basis). Moisture-free, fat-free solids are given also. It is obvious that riboflavin showed some loss as the

[3] The authors are grateful to the College of Home Economics of Cornell University for the panel of experienced and qualified judges. Their excellent cooperation in this project is appreciated.

TABLE 2

Steer 82

Beefsteak Vitamin B Values After Freezing, Storage, and Cooking[1]

Condition of sample	Freezing conditions	Moisture free, fat free solids		Thiamine		Riboflavin		Niacin[2]		Pantothenic acid	Pyridoxine
		0 days' storage	10-mo. storage	0 days' storage	10-mo. storage	0 days' storage	10-mo. storage	0 days' storage	12-mo. storage	10-mo. storage	10-mo. storage
		Dry basis		Dry basis		Dry basis		Dry basis		Dry basis	Dry basis
		pct.	*pct.*								
Raw	Unfrozen	23.47	.....	2.82	.....	5.67	.....	.....	.....	.....	.....
0°F.	Insulated	23.21	23.85	2.43	2.40	5.64	3.00	.....	.....	10.36	5.58
0°F.	Still air,	22.81	23.26	2.44	2.95	6.05	3.54	.....	.....	10.62	5.93
	—50°F.	22.70	23.17	2.92	2.90	5.33	3.09	.....	.....	12.43	4.83
Cooked	Unfrozen	34.36	.....	1.79	.....	5.50	.....	.....	.....	.....	.....
0°F.	Insulated	32.87	32.30	1.49	1.73	4.02	3.13	.....	.....	8.51	6.72
0°F.	Still air,	35.54	31.29	1.53	1.78	5.60	3.55	.....	.....	8.79	6.84
	—50°F.	33.37	29.74	1.65	1.92	5.63	3.32	.....	.....	10.15	6.29
Raw	Unfrozen	23.63	.....	.....	.....	.....	.....	302.6	.....	.....	.....
0°F.	Insulated	22.99	23.27[3]	.....	.....	.....	.....	288.8	327.6	.....	.....
0°F.	Still air,	23.76	23.15[3]	.....	.....	.....	.....	280.3	262.3	.....	.....
	—50°F.	22.19	22.74[3]	.....	.....	.....	.....	305.1	277.9	.....	.....
Cooked	Unfrozen	31.70	.....	.....	.....	.....	.....	264.7	.....	.....	.....
0°F.	Insulated	31.14	31.12[3]	.....	.....	.....	.....	251.1	260.8	.....	.....
0°F.	Still air,	29.65	30.84[3]	.....	.....	.....	.....	256.7	235.3	.....	.....
	—50°F.	32.39	30.67[3]	.....	.....	.....	.....	243.6	237.7	.....	.....

[1] All vitamins in μg. to the gram. [2] Niacin—Steer 20. [3] Stored 12 months. [4] Fat-free dry basis.

TABLE 3

Steer 65

Beefsteak Vitamin B Values After Freezing, Storage, and Cooking[1]

Condition of sample	Freezing conditions	Moisture free, fat free solids		Thiamine		Riboflavin		Niacin		Pantothenic Acid		Pyridoxine	
		0 days' storage	6-mo. storage	0 days' storage	6-mo. storage	0 days' storage	6-mo. storage	0 days' storage	6-mo. storage	0 days' storage	6-mo. storage	0 days' storage	6-mo. storage
				Dry[2] basis	Dry basis	Dry basis	Dry basis	Dry basis	Dry basis	Dry basis	Dry basis	Dry basis	Dry basis
		pct.	*pct.*										
Raw	Unfrozen	23.50	.....	3.83	.....	7.49	.....	277.0	.....	16.17	.....	10.98	.....
0°F.	Insulated	22.26	23.21	3.78	3.33	7.55	6.59	218.3	266.3	18.33	15.38	11.32	8.40
0°F.	Still air	23.01	23.22	3.59	3.56	6.56	6.55	269.9	279.1	17.12	13.61	10.43	8.40
	−50°F.	22.89	23.36	3.64	3.65	6.47	7.41	260.8	295.4	14.02	15.28	10.48	8.35
Cooked	Unfrozen	29.97	.....	2.26	.....	6.77	.....	265.3	.....	16.18	.....	10.91	.....
0°F.	Insulated	29.95	29.73	2.07	2.39	6.88	6.26	245.4	250.3	19.10	13.86	9.52	10.09
0°F.	Still air	31.70	30.73	2.01	2.21	6.50	6.25	238.5	232.4	15.58	11.13	8.80	9.76
	−50°F.	28.60	31.00	2.30	2.17	6.57	6.45	284.3	220.7	15.70	12.84	9.23	9.19

[1] All vitamins in μg. to the gram. [2] Fat-free dry basis.

result of the longer storage period; the six-month storage period did not show this effect.

The niacin figures (Table 2) were taken from Steer 20, and the storage period used for samples from this animal was 12 months. After the storage periods, only insignificant losses were observed; speed of freezing had little effect on the niacin values found. A substantial variation in niacin, when the raw sample was frozen in the insulated box, is shown (Table 3). This was probably caused by an irregularity in determination, because after storage the result was back to normal.

The same table showed a rather high result for the cooked sample frozen at —46°C.(—50°F.), but the corresponding sample, cooked after storage, showed results in line with the other samples.

Thiamine showed losses as a result of cooking, but this loss was substantially the same for the samples from the several speeds of freezing used. This loss in thiamine is in agreement with similar figures found in the literature.

DISCUSSION

In general, results of the vitamin assays show that rate of freezing has no effect on the B-vitamin content of beef.

We do not wish to create the impression that any speed of freezing, however slow, will give good results. It is obvious that unreasonably long delays in the freezing of meat samples might lead to changes, brought about by microorganisms, which would be undesirable. Also, rate of freezing should not be confused with overall time of handling. This work deals only with a comparison of results of the several rates of freezing described. It would be unwise to load a home-freezing cabinet with the unfrozen packages obtained from the entire carcass of a large animal such as a steer. These units do not ordinarily have the capacity to take care of such a large load at one time, and, therefore, such use could end in unsatisfactory results. A smaller number of packages can be easily handled, about 25 pints or pounds in a 20-cu. ft. freezer.

SUMMARY

Rate of freezing was shown to have little effect on the flavor, odor, texture, juiciness, or appearance of beef.

Neither thiamine, riboflavin, niacin, pantothenic acid, nor pyridoxine were measurably altered by the rate of freezing.

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COMPOSITION OF FOOD PLANTS OF CENTRAL AMERICA. II. GUATEMALA

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Early in 1946 a study designed to obtain data on the composition of edible plants found growing in the countries of Central America was initiated in these laboratories. Results from analyses of 121 samples collected in Honduras have been reported by Munsell, Williams, Guild, Troescher, Nightingale, and Harris (1949). In the present paper results are given from analyses of 124 samples of foods considered as vegetables, collected in Guatemala during the period January, 1947, through June, 1948. Results from analyses of 106 additional samples, including 60 of fruits, will be given in a subsequent report.

The procedure for collecting and shipping samples was the same as that described in the first report. Three slurries were made of all except 42 of the 124 samples. The same 13 constituents were determined and methods of analysis were unchanged, except for adoption of the modification for oxidizing ascorbic acid to dehydroascorbic acid suggested by Bolin and Book (1947).

Collection of samples was confined largely to the central highland area of the country, more than one-half coming from the Departments of Guatemala and Sacatepéquez. Samples from areas at lower altitude came from the south central region, chiefly from the Department of Escuintla. Samples from the north central region came from Cobán or nearby towns. Information on altitude, soil type, and rainfall in the several areas where samples originated is given (Table 1).

A total of 49 different foods are represented in the 124 samples analyzed. For 28 of these there were two or more samples and in most cases these were from different areas.

DESCRIPTIONS AND USES OF FOODS STUDIED [1]

EARTH VEGETABLES:

Camote (Earth Vegetables, *Camote*). The sweet potatoes of Sample (a) were grown from stock sent from the Escuela Agrícola Panamericana and probably represent the Nancy Hall variety. The flesh had a pinkish tinge and was rather dry. Flesh of the roots of Sample (b) was very pale cream-yellow, firm, and fairly moist.

Cebolla (Earth Vegetables, *Cebolla*). The onions of Samples (a) and (d) were small and green. Those of Sample (b) were fresh and of various

[1] Descriptions of some of the foods have already been given in the first paper of this series, Munsell *et al.* (1949). This is indicated by the notation in parenthesis following the name of the food and showing where the description was given.

TABLE 1

Information on Altitude, Prevailing Soil Type, and Approximate Average Annual Rainfall in Areas Where Samples Originated

Department	Town	Altitude	Soil	Rainfall [1]	No. of samples
		ft.	*type*	*in.*	
Alta Verapaz	Cobán	4,200[2]	Clay loam	.....	5
Alta Verapaz	Macote	4,200	Clay loam	.....	1
Alta Verapaz	San Cristóbal	4,600	Clay loam	.....	5
Alta Verapaz	San Pedro Carchá	4,200	Clay loam	.....	1
Baja Verapaz	Rabinal	3,500	Clay loam	70	1
Chimaltenango	Comalapa	8,000	Volcanic	60-70	1
Escuintla	Escuintla	2,000	Volcanic	60-70	2
Escuintla	Overo	1,000	Volcanic	60-70	2
Guatemala	Bárcenas	4,800	Volcanic, loam	70	24
Guatemala	Chinautla	6,000	Volcanic	60	1
Guatemala	Guatemala	5,000	Volcanic	60-70	1
Guatemala	La Labor de Castillo	5,500	Volcanic	70	2
Guatemala	Las Vacas	5,000	Volcanic	60	1
Guatemala	Metampa	5,000	Volcanic	60	1
Guatemala	Mixco	5,500	Volcanic	60-70	8
Guatemala	Palencia	6,000	Volcanic	60-70	1
Guatemala	Petapa	4,500	Volcanic	60-70	1
Guatemala	Remasini	5,000	Volcanic	60	1
Guatemala	San Juan Sacatepéquez	5,000-6,000	Volcanic	60-70	3
Guatemala	San Pedro Sacatepéquez	6,500	Volcanic	60-70	1
Guatemala	Santa María	6,000	Volcanic	60	1
Guatemala	Villa Nueva	4,800	Volcanic	50-70	5
Quezaltenango	Almolonga	7,400	Volcanic	70	9
Quezaltenango	Concepción	8,000	Volcanic	70	1
Quezaltenango	Quezaltenango	8,000	Volcanic	70	1
Quezaltenango	San Felipe	5,000	Volcanic	70	1
Quezaltenango	San Martín	8,000	Volcanic	70	1
Quezaltenango	San Sebastián	.....	Volcanic	70	1
Retalhuleu	Retalhuleu	900	Probably volcanic	70	1
Sacatepéquez	Antigua	5,000-6,000	Volcanic	50-70	11
Sacatepéquez	Dueñas	5,000	Volcanic	70	1
Sacatepéquez	Parramos	6,000	Volcanic	70	1
Sacatepéquez	San Bartolo	6,000-7,000	Volcanic	60-70	3
Sacatepéquez	San Lucas	6,000-7,000	Volcanic	60	2
Sacatepéquez	San Lucas Tolimán	6,500	Volcanic	70	1
Sacatepéquez	Santa María de Jesús	7,000	Volcanic	70	1
Sacatepéquez	Santa María del Volcán de Agua	7,000	Volcanic	.....	1
Sacatepéquez	Santiago	6,500-7,000	Volcanic	60-70	2
Sacatepéquez	Santiago Sacatepéquez	6,000	Volcanic	70	1
Santa Rosa	Santa Rosa	7,000	Volcanic	60	1
Sololá	Atitlán	5,000	Volcanic	70	1
Sololá	Panajachel	5,000-6,000	Volcanic	70	3
Suchitepéquez	Mazatenango	1,300	Volcanic	70	4
Suchitepéquez	Santo Tomás	5,000	Volcanic	70	1
Zacapa	Gualán	2,000	Volcanic	60	1
Zacapa	Zacapa	800	Volcanic	30-60	5

[1] Rainfall data for Guatemala, as for most other places in Central America, are scanty. Most of those given are estimates based largely on vegetation and what that vegetation would need to develop.

[2] One sample—Pacaya—grew at an altitude between 1,000 and 2,000 feet.

sizes, while those of Sample (c) were fairly large and ripe. Sample (e) represents the multiplier variety. Samples (a), (b), and (c) were purchased in the market; the other two samples were taken directly from the ground. Sample (e) was of prime quality.

Ichinta (Fruit Vegetables, *Pataste*). Roots of the chayote plant are prepared in various ways but are commonly boiled. Very often they are eaten raw. These roots have thin brown skins and cream-colored, starchy flesh that is moist and heavy.

Nabo. The turnip grows fairly well in the highlands of the tropics. It is not commonly grown in Guatemala. The Indians are said not to like it. Both samples consisted of mature roots having white flesh. The roots of Sample (b) had some purple color near the top.

Papa (Earth Vegetables, *Papa*). The potatoes of the several samples varied considerably in size and appearance. Sample (a) consisted of large potatoes with brown skins and white flesh; Sample (d) of small ones with pink skins and moist, white flesh; and Sample (c) of rather small ones with clear skins and white flesh. The potatoes of Sample (b), obtained from an Indian, were grown at San Pedro Carchá. This area is not suited to potato culture and the specimens were small and of very poor quality.

Puerro (Earth Vegetables, *Puerro*). The bulbs of the leeks used in Sample (a) were mature, while those of Sample (b) were young and small. Sample (a) was taken from the ground; Sample (b) was purchased in the Indian market.

Rábano (Earth Vegetables, *Ribano*). Radishes of Samples (a) and (b) were of the globose variety with red skin and white flesh; those of Sample (c) were long and red (Chinese type). Samples (a) and (b) were taken from the ground; Sample (c) from the market.

Remolacha. Beets are eaten cooked as a vegetable, or with vinegar and olive oil (or other oil) as salad. Sample (a) consisted of mature beets of assorted sizes. Those of Sample (b) were small and poor in quality, a grade commonly seen in the markets. Specimens of Samples (c) and (d) were fairly large, young, and tender. Samples (a) and (c) were taken from the ground; Samples (b) and (d) were purchased in the market.

Salsafí. The oyster plant is not commonly grown in Central America. It may be used as a cooked vegetable, in soups and stews, or chopped in egg dishes.

Yuca (Earth Vegetables, *Yuca*). All samples of the mandioc were obtained from the market and consisted of mature roots. Those of Sample (b) had some purple and brown markings through the flesh.

Zanahoria (Earth Vegetables, *Zanahoria*). The carrots of Samples (a) and (c) were large, while those of Sample (d) varied in size. All were mature. Sample (c) was of the Danvers half-long variety. Sample (d) differed from the others in that the roots were small, short, and thick. They were also fresh, of good color, and tender. Samples (a) and (d) were purchased in the market; (b) and (c) were taken from the ground.

HERBAGE VEGETABLES:

Acelga (Herbage Vegetables, *Acelga*). The leaves of chard used in Sample (a) were small and young. All other samples were from plants

at the stage considered ready to use. Leaves of Sample (e) were large, but were tender and deep green. Samples (a), (b), and (e) were purchased in markets; Samples (c) and (d) were taken directly from the garden.

Apio. Celery is rarely grown in Central America and usually is of poor quality. The sample consisted of eight bunches of poor-quality, unbleached plants. The stalks were small and mostly hollow.

Ayote, flores de (Fruit Vegetables, *Ayote*). Pumpkin (squash) flowers are commonly used as food in Guatemala and probably also in other parts of Central America, although to a lesser extent. The general practice is to take the staminate flowers for food, thus causing no reduction in the crop of fruits. The sample was obtained in the market.

Ayote, hojas de (Fruit Vegetables, *Ayote*). Pumpkin plant leaves are commonly found in markets of Central America. The use of these leaves as well as the growing points of other species of *Cucurbita*—especially by rural populations—is probably even more common than their frequency in markets would indicate, since they are grown in practically all gardens. The sample was purchased in the market.

Berro. Watercress is prized in Central America as a component of salads and is seen frequently in the markets. Although various disinfectant solutions may be and often are used for washing the plants, such cleaning is seldom sufficient to destroy all forms of amoebae that may be present. The sample came from a market.

Bledo. Bledo is widely distributed in Central America and grows most often as a weed in fields or on waste ground. It is used as a cooked vegetable, in soups and stews, or fried with potatoes and onions. Both samples, obtained in the market, consisted of the tender parts of young plants.

Bledo extranjero. This species of *Chenopodium* is native to the United States and Mexico but is relatively rare in Guatemala and is not used commonly as food. When eaten, it is prepared as a cooked vegetable or boiled with onion and chile, then fried in fat. The sample, purchased in a market, consisted of tender shoots and leaves of young plants.

Brusela. Brussels sprouts may be seen occasionally in markets in Central America but they are not cultivated commonly and are of relatively little importance in the diet. When used they are prepared as a cooked vegetable or put into stews or soups. The sample consisted of rather small sprouts and was purchased in a market.

Chipilín. This plant grows commonly as a weed in cornfields and other cultivated areas in Guatemala and occasionally is planted. It is a common item of food and is found in most markets in season, usually tied in small bundles. Some medicinal (sedative) properties are attributed to it and this may account in part for its popularity. The leaves and tender stems are used as a cooked vegetable, in soups and stews, or folded into egg dishes. All samples were obtained in markets.

Coliflor (Herbage Vegetables, *Coliflor*). Sample (a) consisted of small heads of cauliflower taken directly from the plants. Only the flower clusters and upper parts of the stems were used. Sample (b) was prepared

from four heads in excellent condition purchased in the market. They were quartered for sampling.

Colinabo (Herbage Vegetables, *Colinabo*). The sample of kohlrabi included 11 of the thickened stems, pale-green in color. These were taken directly from the field and quartered for sampling.

Espinaca (Herbage Vegetables, *Espinaca*). Sample (a) of the New Zealand Iceplant was purchased in the market. The plants were washed thoroughly but even then probably retained considerable volcanic dust. Only the terminal parts were used. Sample (b) was taken directly from the field and was not washed. The plants were tender and in good condition.

Güisquil, puntas de (Fruit Vegetables, *Pataste*). The tender new growths of chayote plants are cooked as a green vegetable or boiled and added to egg dishes. All of the samples consisted of the tender growing points. Samples (a), (b), and (d) were obtained in the market. Specimens for Samples (b) and (d) were washed before slurries were made.

Izote, flores de. The yucca is widely distributed throughout Central America as a cultivated or semi-cultivated plant. It is used as an ornamental, as well as a source of food, and in some areas aids in control of erosion.

The flowers are prized highly as food and are found in many markets in season. The ovary and stamens are generally removed in preparation for eating, although the whole flower may be used. The most common method of preparation is to boil or fry, or to fold into egg batter. They may also be used in stews or salad. Both samples were obtained in the market.

Lechuga. The 100 or more horticultural variations of lettuce may be reduced to four main types: var. *capitata* (DC.) Hort., head or cabbage lettuces; var. *intybacea* (Jacq.) Hort., cut-leaved lettuces; var. *romana* Hort., Cos, or romaine lettuces; and var. *angustana* Hort., narrow-leaved lettuces. All of these variations may be found in cultivation in Central America although two, var. *capitata* and var. *romana*, are the ones usually grown. Lettuce is not greatly appreciated by the populations of Central America and is grown chiefly for foreign colonies. The product sold is usually of indifferent quality although good lettuce can be grown. Sample (a) was taken from the plant; Sample (b) was purchased in the market.

Macuy (Macuí). This plant is widely distributed as a weed in all temperate and tropical regions. In Guatemala it is eaten as a green. Some medicinal (sedative) properties are ascribed to the plant by the native peoples. The sample was purchased in the Antigua market.

Mostaza. Field mustard grows abundantly in some areas in the highlands of Central America. In some regions large quantities are used as food, usually as a cooked green. The plants of Sample (a) were purchased in the market and were just under the flower stage; those for Sample (b) were taken from the ground and were three or four weeks from seed and just beginning to flower. In each case the plants were washed before samples were prepared.

Nabo. See *Mostaza.* This name is applied by the Indians to *mostaza* or field mustard.

Pacaya. Inflorescences of various palms, both wild and cultivated, are highly prized as food in Guatemala and large quantities are brought to the market from Cobán. The inflorescences are cut before the sheaths open. The very young ones are removed, dipped into egg batter, and fried.

Pito. This tree serves for shade and fencerows, as well as for a source of food. It may contain the same alkaloids known to be present in other species of the genus and is thought to have curare-like properties. A brew of the young shoots is used as a narcotic, and leaves and flowers placed under the pillow are believed to induce sleep. The unopened buds and the flowers, eaten as a vegetable with meat, in stews, and in egg dishes, are supposed to exert a calming effect and give a feeling of well-being. The tender shoots and leaves also may be eaten. The sample was obtained from an Indian who was collecting it.

Repollo (Herbage Vegetables, *Repollo*). Sample (d) of cabbage was purchased in the market. The other samples were collected in the field. Sample (a) consisted of five small heads of common cabbage. Sample (b) was taken at a season (December) when cabbages were not plentiful and the heads were light for their size. The heads of Sample (c) had green outer leaves which were removed before slurries were prepared. Sample (d) was a variety of purple cabbage and the heads were small.

Ruibarbo. Rhubarb is rarely found in Central America and is not eaten to any extent, if at all. The sample was from an experimental plot at the Escuela Nacional de Agricultura. Thickened leaf petioles, with the epidermis intact, were used for the prepared samples.

Verdolaga (Herbage Vegetables, *Verdolaga*). Specimens of purslane were purchased in the market and were washed before samples were prepared. Only the tender tips and leaves were used.

Brassica juncea var. foliosa Bailey L. Leaves of this plant may be used cooked as a green or uncooked in salads. Specimens were taken directly from growing plants, and whole leaves and tender petioles were used in the prepared samples.

FRUIT VEGETABLES:

Aguacate (Fruit Vegetables, *Aguacate*). Each sample of avocado was purchased in a market and all consisted of ripe fruits. Fruits of Samples (a), (b), (c), and (e) were of the Guatemalan type with thick skins and large seeds and were pear-shaped or ovoid. Sample (b) had dark skin. Fruits of Sample (d) had purple-colored, thin skins, large seeds, and considerable fiber throughout the flesh. Prepared samples consisted of flesh only.

Aguacatillo. Avocados of the "Mexican Race" are similar to other groups, except the skin of the ripe fruit is thin and usually purple-black, and the flesh has an anise odor and taste. This form is rarely seen in Guatemala. The sample consisted of ripe fruits, with green, fine-flavored, smooth, soft flesh. These were purchased in the market.

Ayote and *Güicoy* (Fruit Vegetables, *Ayote*). The fruits of Samples (a) and (c) of the pumpkins, *ayote*, were immature and tender with green skins and pale-green flesh—Sample (c) was very pale green. For the prepared samples whole fruits were washed, wiped dry, and diced so

that the sample included skin, flesh, and seeds. The fruits of Sample (b), a variety rare in Guatemala, had thin, rough, bright-yellow skin and very pale-green, dry, soft flesh. The seed cavity of these fruits was large and the flesh thin. Only the flesh was used in the prepared samples. Fruits for Sample (a) were taken from the vine; those for Samples (b) and (c) were purchased in the market.

The samples of squash, *güicoy*, represent several variations. Sample (a) consisted of fruits of the summer squash type. These were very young and tender. Fruits of Sample (b) were flattened and had a thick, hard, ridged skin, mottled greenish-yellow or black. The flesh was lemon-yellow in color, and dry. Fruits of Sample (c) were oblate. The skin was golden-yellow in color, thick and hard, and the flesh was firm, moist, and pale yellow-green to green in color. Sample (d) was made up of fully ripe fruits of a fluted variety, having hard yellow skins with many stone cells and moist, golden-yellow flesh. Fruits of Sample (e) were flattened and had hard, ribbed skins and firm, yellow flesh. The seeds were soft. Whole fruits were used for the subsamples of Samples (a) and (e) and flesh only for the other samples. All samples were obtained in the market. Fruits of the varieties represented by Samples (b), (c), and (d), in addition to use as a vegetable, are sometimes used for making a sweet.

Berengena (Fruit Vegetables, *Berengena*). The sample of eggplant comprised mature fruits with purple skin and nearly white, rather dry flesh. The fruits were peeled for sampling.

Caiba. Caibas are found infrequently in markets in Guatemala, although several species of the genus are known in Central America. The fruits are produced in abundance on a vine and are present the year around. These fruits are occasionally used as food. Only the skin and underlying flesh are eaten. Sample (a) was taken from the vine; Sample (b) was obtained in the market. Only the thick skin and flesh were used in the prepared samples.

Calabaza (Fruit Vegetables, *Ayote*). The sample consisted of the flesh only of six small turbinate squashes, in a condition ready for use.

Chilacayote. This plant has been tentatively determined as *Cucurbita ficifolia* Bouché. Prof. L. H. Bailey, a specialist on cucurbits, has recently published a note, Bailey (1948), to the effect that the Central American plant may belong to an undescribed species. The fruit is large and when eaten in Central America is prepared as a cooked vegetable or used in soups. A sweet may also be prepared from the flesh. The seeds, like those of some other cucurbits, may be eaten like nuts. The sample was prepared by taking longitudinal, wedge-shaped slices from five ripe fruits.

Chile. This variety of capsicum is a cultigen, doubtless of Central American origin. As grown in the wet climate of the Cobán area, the plant may be either an annual or a perennial and is rather common where the sample was secured. A large number of small, long peppers, including both green and ripe fruits, made up the sample. In this variety the calyx surrounds the base of the fruit. Flesh and seeds were used in the prepared sample.

Chile chamborote; Pimienta (Fruit Vegetables, *Chile dulce*). Because of their high cost sweet green peppers are used most commonly as a condi-

ment with other foods, although they may be prepared stuffed. Fruits of the *chile chamborote* variation have almost paper-thin flesh and are consequently very light in weight. The flavor is mild but when eaten raw a slight sharp taste develops in the mouth after a few minutes. For the prepared sample the fruits were washed and left to dry overnight. The peduncle and seeds were then removed and the flesh and skin chopped. The sample of the variation *pimienta* consisted of elongated fruits. The skin and flesh were used for the prepared sample.

Chile diente de perro; Chile pacaya. The majority of the small hot peppers probably belongs to the variety *baccatum* of the species *frutescens*, and for purposes of this study all small hot peppers, in which the calyx does not embrace the base of the fruit, are so classified. The sample of *chile diente de perro* consisted of a mixture of red and green fruits. These fruits are very hot and are used as flavoring, either in sauces or cooked with other foods. The sample of *chile pacaya* included mostly green fruits weighing about three to the gram. They are used primarily in sauces and as flavoring. The prepared samples included whole fruits with seeds.

Chile guaque; chile jalapeño, and *chile verde.* This variety of "chile pepper" is rather common in Guatemala and there are several forms of it. These hot peppers are used as seasoning in other foods and for sauces. The fruits of the six samples analyzed showed considerable variation in appearance. Sample (a) of *chile guaque* consisted of long, slender, green fruits. The epidermis of these fruits becomes black upon ripening. Fruits of Sample (b) were not ordinary *chiles guaques.* They were green and thicker than fruits of Sample (a).

Fruits of all three samples of *chile jalapeño* were short, thick, and smooth-skinned. Those of Sample (a) were green, of Sample (c) red, and of Sample (b) mixed green and red.

Fruits of Sample (a) of *chile verde* resembled those of Sample (b) of *chile guaque* and, in fact, are called *chile guaque* in Antigua and Guatemala City. In ripe fruits of this variation the epidermis is purple. Fruits of Sample (b), called *chile verde* for no particular reason, were small and pale yellow-green in color. Entire fruits—skin, flesh, and seeds—were used in the prepared samples of Sample (b) of *chile jalapeño* and Samples (a) and (b) of *chile verde.* In all other subsamples seeds were discarded.

Chile jalapeño. See *Chile guaque.*

Chile japonés. This is a small hot pepper, bright orange-yellow in color, rather firm, and fairly thick. When eaten, the flavor is not excessively pungent at first but after an hour or two a burning sensation develops in the mouth that to some is almost unbearable. The fruit is used only for seasoning. The prepared sample consisted of the flesh and skin of several fruits.

Chile pacaya. See *Chile diente de perro.*

Chile verde. See *Chile guaque.*

Güicoy. See *Ayote.*

Güisquil; Perulera (Fruit Vegetables, *Pataste*). The chayote is a relatively cheap vegetable and is used alone as a cooked vegetable, in soups, or folded into egg batter. Samples (a), (b), and (d) of *güisquil* were purchased in the market; Sample (c) was purchased from the grower.

Fruits of Samples (a), (c), and (d) had dark skins while those of Sample (b) were light green. The flesh of fruits of Samples (b) and (c) was very pale, while that of Samples (a) and (d) had a greenish tinge. Fruits of Sample (d) were spineless, of Samples (a) and (c) almost spineless, while those of Sample (b) were spiny. All prepared samples were made with peeled fruits. The *perulera* variation of the chayote has cream or pale-green skin; white flesh, and is spineless. It is perhaps the best of the chayotes and is used raw or as a cooked vegetable, either plain or folded into egg batter. Samples were purchased in the market and the prepared samples were made with peeled fruits.

Miltomate; Tomatillo. The ground cherry is possibly native to Central America and occurs as a weed. The fruit is seen commonly in markets and where it does not grow or is out of season it is brought in from other localities. Fruits represented by Sample (a) of *miltomate* and (c) of *tomatillo* are used in stews and soups, chopped in egg, or fried, and when ripe may be used the same as tomatoes. Fruits represented by Sample (b) of *miltomate* are used almost exclusively with chiles to make a sauce. Fruits of Sample (a) were green; those of Sample (b) were mostly green with some turning purple. Whole fruits were used in the prepared samples.

Pepino (a) and (b) (Fruit Vegetables, *Pepino*). Fruits of Sample (a) of cucumber, collected in the field, were green; those of Sample (b), purchased in the market, were beginning to turn yellow. Both prepared samples were made from peeled fruits.

Pepino (c), (d), and (e). The melon pear is much appreciated in Central America and in season is to be found in many markets. The skin of this fruit is pale-green with longitudinal purple bands and the flesh is very pale-yellow or green. While still green the fruit may be cooked, but it is more commonly eaten ripe as a fruit out of hand. All samples were obtained in the market. Whole fruits were used for preparation of Sample (c); fruits for the other prepared samples were peeled.

Perulera. See *Güisquil.*

Pimienta. See *Chile chamborote.*

Tomate (Fruit Vegetables, *Tomate*). Tomatoes in Central America are used in the usual ways in salads, soups, and stews, and as a vegetable. Samples (a) and (b) were purchased in the market; Sample (c) was taken from the plants. Fruits of Sample (a) were globular in shape, ripe, and of good quality; those of Sample (b) were small, irregular in shape, and of poor quality; and those of Sample (c), horticultural variety *Ingegnoli*, were vine-ripe, red, and of fine flavor. All prepared samples included skin, seeds, and flesh.

Tomate extranjero. This fruit is a native of Brazil and is not found commonly in Central America. It is used primarily for jam or as a cooked fruit in heavy syrup. The fruits for the sample, taken from a tree, were firm and ripe. The prepared sample consisted of the flesh only.

Tomatillo (a) (Fruit Vegetables, *Miltomate*). The sample was taken from the plants and consisted of about 170 fruits, nearly ripe. The prepared sample was made from whole berries.

Tomatillo (b). The species of *Physalis* are difficult to distinguish. The present species is undoubtedly Central American in origin and is one of two species used as food. It is found commonly in the markets of Guatemala but is rare elsewhere. The fruits are used principally with chile in the preparation of hot sauces. They may also be used in salads or as a cooked vegetable. The sample, *tomatillo* (b), consisted of approximately 100 nearly mature, good-sized fruits collected from the plants. Husks were removed and the fruits washed and superficially dried. The prepared sample included skin, flesh, and seeds.

Tomatillo (c). See *Miltomate*.

RESULTS AND DISCUSSION

Results from analyses of the 124 samples of vegetables are shown (Table 2). These values are expressive of the amounts of the respective constituents in 100 grams of raw, edible food material.

Several foods gave relatively high values for one or more constituents as indicated in the following discussion.

Nabo. The two samples of turnip differed significantly in their content of niacin, one containing 1.511 and the other only 0.646 mg.

Papa. All four samples of potato show relatively high values for niacin content and two samples, (c) and (d), gave significantly high values. Sample (d) also gave a high value for thiamine content, 0.194 mg., which is more than twice the value for any of the other three samples.

Acelga. Except for variations in iron content from 2.07 to 15.49 mg., and in carotene content from 0.026 to 2.720 mg., the five samples of Swiss chard were remarkably similar in composition. Sample (a), with the high value for iron (15.49 mg.) and very low value for carotene (0.026 mg.), consisted of leaves from very young plants. Sample (e), with the lowest value for iron (2.07 mg.), was made up of thick, heavy leaves. Swiss chard is not grown commonly in Central America at the present time.

Hojas de ayote. The leaves and tender points of squash and pumpkin plants are used extensively as food in Central America. The high values obtained for several constituents—calcium 127.5 mg., iron 11.53 mg., carotene 2.800 mg., thiamine 0.305 mg., riboflavin 0.410 mg., niacin 2.312 mg., and ascorbic acid 78.9 mg.—in the sample analyzed, show this is a food of high over-all nutritive value.

Berro. The one sample of watercress was high in content of iron (9.36 mg.) and contained a fair amount of calcium (95.3 mg.). In the amounts eaten, watercress may be an important source of these two constituents in the diet.

Bledo. This plant gave high values for calcium (252.3 and 315.0 mg.), iron (43.38 and 12.42 mg.), and riboflavin (0.267 and 0.288 mg.). One sample also showed a high content of carotene (5.841 mg.) and of ascorbic acid (92.0 mg.), and both samples contained significant amounts of niacin (1.252 and 1.282 mg.).

Bledo extranjero. The sample of lambsquarters showed high values for calcium (155.6 mg.), iron (2.99 mg.), carotene (6.317 mg.), riboflavin (0.469 mg.), and ascorbic acid (109.0 mg.), and a relatively high value for niacin (1.238 mg.).

TABLE 2

Composition of Food Samples From Guatemala

Name of food sampled			Place sample originated[1]	Constituents measured and yields per 100 gm.												
Spanish	Scientific	English		Moisture	Ether extract	Crude fiber	Nitrogen	Ash	Calcium	Phosphorus	Iron	Carotene	Thiamine	Riboflavin	Niacin	Ascorbic Acid-Total
	EARTH VEGETABLES			*gm.*	*gm.*	*gm.*	*gm.*	*gm.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*
Camote (a)	*Ipomaea Batatas* (L.) Lam.	Sweet potato	Bárcenas	71.8	0.12	0.9	.155	1.02	17.0	62.8	1.18	.128	.082	.045	.764	64.0
Camote (b)	*Ipomaea Batatas* (L.) Lam.	Sweet potato	Dueñas	66.2	0.55	1.2	.222	.84	19.7	18.2	0.93	.038	.125	.044	.812	49.0
Cebolla (a)	*Allium Cepa* L.	Onion	Metampa	82.5	0.09	1.0	.351	.57	42.5	32.1	0.70	.000	.089	.037	.356	7.9
Cebolla (b)	*Allium Cepa* L.	Onion	Panajachel	89.9	0.59	0.6	.190	.39	22.9	40.6	0.66	.028	.037	.021	.254	13.5
Cebolla (c)	*Allium Cepa* L.	Onion	Panajachel	89.7	0.06	0.5	.210	.42	21.5	36.4	0.40	.005	.047	.021	.133	7.0
Cebolla (d)	*Allium Cepa* L.	Onion	Bárcenas	92.6	0.12	0.8	.229	.53	46.1	41.9	0.32	.021	.080	.054	.468	21.1
Cebolla (e)	*Allium Cepa* L. var. *multiplicans* Bailey	Onion	Bárcenas	85.5	0.13	0.9	.262	.68	51.3	50.9	0.95	.001	.056	.046	.395	14.1
Ichinta	*Sechium edule* (Jacq.) Sw.	Chayote root	Mixco	72.0	0.09	0.4	.408	1.05	4.4	84.0	1.03	.000	.070	.040	1.092	21.4
Nabo (a)	*Brassica Rapa* L.	Turnip	Bárcenas	91.1	0.15	1.1	.169	.88	45.3	27.8	0.56	.000	.028	.030	1.511	33.3
Nabo (b)	*Brassica Rapa* L.	Turnip	San Cristóbal	92.5	0.16	0.6	.142	.71	24.9	35.9	2.04	.012	.026	.023	.646	25.1
Papa (a)	*Solanum tuberosum* L.	Potato	Santa Rosa	74.3	0.07	0.3	.326	.86	2.4	45.3	0.52	.002	.079	.027	1.480	47.6
Papa (b)	*Solanum tuberosum* L.	Potato	San Pedro Carchá	76.7	0.11	1.2	.381	.87	5.7	46.7	4.55	.000	.057	.027	1.725	14.4
Papa extranjera (c)	*Solanum tuberosum* L.	Potato	Concepción	79.4	0.29	0.3	.363	.85	4.3	38.2	0.75	.002	.077	.029	2.265	29.6
Papa Polima (d)	*Solanum tuberosum* L.	Potato	San Martín	70.4	0.45	0.7	.372	.96	2.7	31.9	1.12	.000	.194	.027	2.455	20.3
Puerro (a)	*Allium Porrum* L.	Leek	Bárcenas	82.4	0.20	1.2	.450	.91	38.9	66.7	0.87	.000	.112	.067	.720	13.6
Puerro (b)	*Allium Porrum* L.	Leek	Villa Nueva	84.5	0.04	1.1	.265	.74	45.5	48.9	1.16	.020	.068	.066	.551	16.7
Rábano (a)	*Raphanus sativus* L.	Radish	Remasini	94.4	0.15	1.0	.180	.90	35.6	27.4	1.80	.000	.035	.033	.336	25.6
Rábano (b)	*Raphanus sativus* L.	Radish	Bárcenas	95.0	0.02	0.5	.137	.83	16.7	19.2	0.97	.003	.022	.031	.249	22.2
Rábano (c)	*Raphanus sativus* L.	Radish	Almolonga	94.6	0.04	0.9	.090	.81	27.4	26.0	0.30	.007	.020	.021	.235	27.3
Remolacha (a)	*Beta vulgaris* var. *crassa* Alef.	Beet	Bárcenas	85.5	0.13	0.8	.263	.80	10.9	43.0	0.63	.003	.017	.033	.267	5.1
Remolacha (b)	*Beta vulgaris* var. *crassa* Alef.	Beet	Cobán	90.4	0.07	0.8	.195	1.03	14.4	14.7	1.68	.015	.013	.036	.268	3.8
Remolacha (c)	*Beta vulgaris* var. *crassa* Alef.	Beet	Bárcenas	90.2	0.04	0.6	.292	.99	10.0	23.5	0.58	.006	.024	.040	.303	7.1

Remolacha (d)	*Beta vulgaris* var. *crassa* Alef.	Beet	Almolonga	87.2	0.03	0.8	.218	.56	12.2	36.6	0.70	.003	.024	.039	.263	4.0
Salsafí	*Tragopogon porrifolius* L.	Oyster plant	San Lucas	74.4	0.17	1.6	.194	1.04	36.8	47.8	1.88	.009	.033	.035	.252	24.3
Yuca (a)	*Manihot esculenta* Crantz	Mandioc	Overo	62.4	0.19	2.2	.169	1.13	19.9	52.6	0.55	.002	.064	.046	.765	37.2
Yuca (b)	*Manihot esculenta* Crantz	Mandioc	Mazatenango	50.3	0.42	0.7	.149	.83	31.7	53.3	0.92	.000	.092	.047	.933	55.3
Yuca (c)	*Manihot esculenta* Crantz	Mandioc	Overo	67.0	0.19	0.9	.139	1.00	20.9	59.7	0.35	.009	.063	.031	.559	35.3
Zanahoria (a)	*Daucus Carota* L.	Carrot	Antigua	90.0	0.13	0.8	.085	.73	26.4	24.2	0.98	3.420	.047	.027	.616	7.8
Zanahoria (b)	*Daucus Carota* L.	Carrot	Bárcenas	88.9	0.07	0.8	.169	.89	31.3	40.6	1.20	6.890	.065	.032	.490	7.5
Zanahoria (c)	*Daucus Carota* L.	Carrot	Bárcenas	89.0	0.03	0.8	.211	1.75	33.5	32.4	0.31	11.152	.050	.042	.502	6.8
Zanahoria (d)	*Daucus Carota* L.	Carrot	Almolonga	89.3	0.05	0.9	.124	.66	23.8	26.3	0.33	6.098	.044	.033	.522	5.2
	HERBAGE VEGETABLES															
Acelga (a)	*Beta vulgaris* var. *cicla* Moq.	Chard	San Lucas	92.5	0.23	0.8	.391	1.65	66.8	29.8	15.49	.026	.067	.188	.533	25.5
Acelga (b)	*Beta vulgaris* var. *cicla* Moq.	Chard	Santiago	93.5	0.17	0.7	.330	1.37	51.4	28.9	7.77	1.970	.052	.180	.587	23.5
Acelga (c)	*Beta vulgaris* var. *cicla* Moq.	Chard	Cobán	92.0	0.52	0.7	.452	1.43	63.9	38.3	4.10	2.720	.089	.254	.931	38.5
Acelga (d)	*Beta vulgaris* var. *cicla* Moq.	Chard	Bárcenas	90.7	0.27	0.8	.553	1.42	66.0	43.4	5.71	2.440	.120	.201	.596	50.7
Acelga (e)	*Beta vulgaris* var. *cicla* Moq.	Chard	Almolonga	92.0	0.13	1.1	.424	1.43	80.0	35.7	2.07	2.232	.080	.220	.651	49.0
Apio	*Apium graveolens* L.	Celery	Almolonga	94.1	0.07	0.9	.108	1.11	44.0	23.4	2.06	.213	.031	.070	.389	12.3
Ayote, flores de	*Cucurbita Pepo* L.	Squash flowers	Villa Nueva	95.0	0.22	0.5	.238	.60	29.6	37.8	5.76	.251	.029	.074	.614	13.1
Ayote, hojas de	*Cucurbita Pepo* L.	Pumpkin leaves	San Pedro Sacatepéquez	88.8	0.62	2.4	.944	1.88	127.5	135.6	11.53	2.800	.305	.410	2.312	78.9
Berro	*Nasturtium officinale* R. Br.	Watercress	Antigua	94.1	0.34	0.7	.376	1.31	95.3	51.5	9.36	1.011	.077	.131	.704	40.6
Bledo (a)	*Amaranthus hybridus* L.	.....	San Juan Sacatepéquez	86.8	0.72	2.8	.800	2.55	252.3	71.7	43.38	.218	.075	.267	1.252	58.4
Bledo (b)	*Amaranthus hybridus* L.	.....	Antigua	85.8	0.46	1.5	.690	2.75	315.0	82.0	12.42	5.841	.094	.288	1.282	92.0
Bledo extranjero	*Chenopodium Berlandieri* Moq.	Lambs quarters	Mixco	83.0	0.93	2.5	1.147	3.48	155.6	68.4	2.99	6.317	.167	.469	1.238	109.0
Brusela	*Brassica oleracea* var. *gemmifera Zenker*	Brussels sprouts	Antigua	85.2	0.21	1.3	.864	1.24	32.8	101.3	1.51	.079	.191	.126	.833	97.0
Chipilín (a)	*Crotalaria longirostrata* Hook. and Arn.	.....	Antigua	83.0	0.65	1.7	1.147	1.64	398.3	65.5	7.86	9.355	.394	.773	2.765	133.0
Chipilín (b)	*Crotalaria longirostrata* Hook. and Arn.	.....	Santa María del Volcán deAgua	82.2	1.00	2.1	1.225	1.51	217.5	77.9	5.73	.158	.324	.570	2.000	141.5
Chipilín (c)	*Crotalaria longirostrata* Hook. and Arn.	.....	La Labor de Castillo	81.1	0.76	2.4	1.086	1.47	200.1	68.7	4.10	6.437	.305	.411	2.058	152.5

TABLE 2 *(Continued)*

Composition of Food Samples From Guatemala

Name of food sampled			Place sample originated[1]	Constituents measured and yields per 100 gm.												
Spanish	Scientific	English		Moisture	Ether extract	Crude fiber	Nitrogen	Ash	Calcium	Phosphorus	Iron	Carotene	Thiamine	Riboflavin	Niacin	Ascorbic Acid-Total
				gm.	*gm.*	*gm.*	*gm.*	*gm.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*
Coliflor (a)	*Brassica oleracea* var. *botrytis* L.	Cauliflower	Bárcenas	90.6	0.19	0.9	.469	.94	19.7	55.3	1.05	.005	.070	.110	.737	**80.0**
Coliflor (b)	*Brassica oleracea* var. *botrytis* L.	Cauliflower	Almolonga	90.8	0.04	1.2	.404	.72	28.5	54.4	0.79	.025	.100	.095	.628	**83.0**
Colinabo	*Brassica caulorapa* (DC.) Pasq.	Kohlrabi	Bárcenas	88.0	0.12	0.9	.426	.91	39.1	30.7	0.30	.002	.063	.030	.521	**115.2**
Espinaca (a)	*Tetragonia expansa* Thunb.	New Zealand Iceplant	Santiago	91.9	0.25	0.8	.425	1.51	47.4	40.7	5.16	.057	.009	.175	.530	**30.3**
Espinaca (b)	*Tetragonia expansa* Thunb.	New Zealand Iceplant	Bárcenas	91.5	0.24	0.8	.484	1.69	66.2	49.3	2.04	2.640	.040	.201	.572	**50.1**
Güisquil, puntas de (a)	*Sechium edule* (Jacq.) Sw.	.....	San Juan Sacatapéquez	88.9	0.42	1.0	.665	1.45	47.3	120.3	8.17	.030	.089	.208	1.190	**14.3**
Güisquil, puntas de (b)	*Sechium edule* (Jacq.) Sw.	.....	Mixco	90.3	0.24	1.3	.539	.98	62.9	90.1	2.06	.847	.047	.172	.919	**10.5**
Güisquil, puntas de (c)	*Sechium edule* (Jacq.) Sw.	.....	Cobán	91.4	0.66	1.3	.490	.84	21.7	59.0	1.39	1.065	.043	.124	1.023	**24.3**
Güisquil, puntas de (d)	*Sechium edule* (Jacq.) Sw.	.....	Mixco	90.2	0.56	1.0	.744	1.20	52.2	102.2	3.82	1.417	.097	.185	1.018	**15.8**
Izote, flores de (a)	*Yucca elephantipes* Regel	.....	Chinautla	82.2	0.32	0.9	.364	.85	16.6	67.3	2.39	.026	.207	.152	1.900	**520.0**
Izote, flores de (b)	*Yucca elephantipes* Regel	.....	Petapa	89.0	0.52	0.7	.291	.67	9.3	40.5	1.03	.003	.094	.175	1.460	**234.5**
Lechuga (a)	*Lactuca sativa* L. var. *capitata* Hort.	Head lettuce	Las Vacas	94.5	0.16	0.6	.256	.74	18.7	46.5	1.84	.042	.131	.081	.424	**15.0**
Lechuga (b)	*Lactuca sativa* L. var. *capitata* Hort.	Head lettuce	Almolonga	94.9	0.23	0.6	.209	.59	27.0	33.0	0.64	.287	.103	.069	.436	**15.0**
Macuy o Macuí	*Solanum nigrum* L.	.....	Santa María de Jesús	88.0	0.98	1.2	.836	1.52	155.2	55.6	10.71	.218	.187	.345	.987	**71.5**
Mostaza (a)	*Brassica campestris* L.	Field mustard	Mixco	90.7	0.80	1.0	.583	1.14	170.8	46.7	4.14	1.025	.115	.219	1.031	**71.5**

Mostaza (b)	*Brassica campestris* L.	Field mustard	Quezaltenango	89.6	0.37	1.3	.650	1.31	191.5	55.6	1.51	4.198	.128	.277	.973	139.5
Pacaya	*Chamaedorea Tepejilote* Liebm.	.....	Cobán	83.6	0.38	1.7	.868	2.25	421.6	128.4	1.97	.014	.056	.111	.817	9.3
Pito	*Erythrina Berteroana* Urban	.....	Villa Nueva	82.1	0.30	2.6	.698	1.41	109.0	87.9	1.61	.159	.157	.221	1.302	48.5
Repollo (a)	*Brassica oleracea* var. *capitata* L.	Cabbage	Bárcenas	90.3	0.18	0.9	.455	.87	58.0	51.3	0.68	.005	.078	.078	.526	65.6
Repollo (b)	*Brassica oleracea* var. *capitata* L.	Cabbage	Cobán	93.8	0.08	0.6	.188	.47	50.8	22.7	0.55	.059	.032	.036	.224	32.4
Repollo (c)	*Brassica oleracea* var. *capitata* L.	Cabbage	Bárcenas	93.0	0.13	0.7	.216	.54	40.2	29.6	0.30	.008	.078	.040	.220	39.4
Repollo morado (d)	*Brassica oleracea* var. *capitata* L.	Cabbage	San Bartolo	88.1	0.14	1.0	.348	.81	42.1	40.1	0.65	.000	.077	.045	.335	69.5
Ruibarbo	*Rheum Rhaponticum* L.	Rhubarb	Bárcenas	94.6	0.30	0.7	.121	.74	30.7	15.9	0.26	.039	.038	.009	.282	15.3
Verdolaga	*Portulaca oleracea* L.	Purslane	Mixco	92.4	0.40	0.8	.295	1.38	74.1	30.9	1.79	1.779	.028	.131	.523	26.0
.....	*Brassica juncea* var. *foliosa* Bailey	Leaf mustard	Bárcenas	87.4	0.27	1.1	.575	1.97	60.8	46.1	6.66	1.068	.089	.330	.760	67.0
	FRUIT VEGETABLES															
Aguacate (a)	*Persea americana* Mill.	Avocado	Antigua	79.8	13.30	1.3	.265	1.00	5.1	41.3	0.50	.154	.062	.120	1.575	5.3
Aguacate (b)	*Persea americana* Mill.	Avocado	San Lucas Tolimán	65.7	18.59	1.1	.258	.87	9.0	20.7	0.99	.058	.063	.082	1.239	5.4
Aguacate (c)	*Persea americana* Mill.	Avocado	Antigua	74.5	17.19	1.5	.345	1.33	11.8	40.8	0.71	.154	.083	.116	1.773	4.5
Aguacate (d)	*Persea americana* Mill.	Avocado	Escuintla	84.3	7.03	1.5	.306	.79	20.4	34.7	0.50	.043	.083	.139	2.035	21.3
Aguacate verde (e)	*Persea americana* Mill.	Avocado	Santo Tomás	69.4	19.80	1.8	.347	1.68	6.2	64.1	1.28	.475	.117	.176	1.627	6.9
Aguacatillo	*Persea americana* var. *drymifolia* (Schlecht. and Cham.) Blake	Mexican avocado	Escuintla	85.7	6.45	1.4	.185	.87	6.7	26.4	0.64	.025	.056	.082	1.258	19.9
Ayote (a)	*Cucurbita Pepo* L.	Pumpkin	Bárcenas	94.9	0.03	0.3	.197	.48	20.5	27.5	0.43	.084	.038	.031	.418	10.1
Ayote (b)	*Cucurbita Pepo* L.	Pumpkin	Almolonga	89.5	0.04	0.5	.158	.35	10.0	24.4	0.47	.131	.060	.045	.441	21.9
Ayote tierno (c)	*Cucurbita Pepo* L.	Pumpkin	Almolonga	93.8	0.04	0.5	.120	.48	20.7	33.7	0.50	.143	.044	.046	.357	20.6
Berengena	*Solanum Melongena* var. *esculentum* (Dun.) Nees	Eggplant	Zacapa	90.8	0.18	1.2	.229	.55	7.8	34.3	0.54	.003	.049	.051	.823	8.2
Caiba (a)	*Cyclanthera pedata* Schrad.	.....	Bárcenas	93.4	0.11	0.7	.150	.58	12.1	27.1	0.69	.011	.041	.041	.387	11.8
Caiba (b)	*Cyclanthera pedata* Schrad.	.....	San Cristóbal	93.8	0.28	0.6	.100	.65	13.8	28.6	1.86	.062	.027	.042	.337	16.3

TABLE 2 *(Concluded)*

Composition of Food Samples From Guatemala

Name of food sampled			Place sample originated[1]	Constituents measured and yields per 100 gm.												
Spanish	Scientific	English		Moisture	Ether extract	Crude fiber	Nitrogen	Ash	Calcium	Phosphorus	Iron	Carotene	Thiamine	Riboflavin	Niacin	Ascorbic Acid Total
				gm.	*gm.*	*gm.*	*gm.*	*gm.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*
Calabaza	*Cucurbita maxima* var. *Melopepo* (L.) Alef.	Squash, turbinate	Bárcenas	95.2	0.11	0.4	.128	.39	18.2	14.3	2.27	.001	.025	.025	.347	16.6
Chilacayote	*Cucurbita ficifolia* Bouché	.....	San Bartolo	93.9	0.26	0.5	.078	.43	10.0	5.2	0.43	.005	.047	.013	.230	1.6
Chile	*Capsicum annuum* var. *acuminatum* Fingh.	.....	San Cristóbal	79.3	3.02	6.6	.612	1.03	16.9	59.3	1.12	2.360	.142	.164	1.991	176.7
Chile chamborote	*Capsicum annuum* var. *grossum* (L.) Sendt.	.....	Guatemala City	90.2	0.24	2.4	.274	.57	6.6	28.7	0.70	.....	.078	.028	1.173	86.3
Chile diente de perro	*Capsicum frutescens* var. *baccatum* (L.) Irish	.....	Villa Nueva	77.7	1.99	8.8	.540	1.13	37.6	64.6	0.91	.413	.129	.118	2.830	92.8
Chile guaque (a)	*Capsicum annuum* var. *longum* (DC.) Sendt.	.....	Parramos	90.8	0.30	2.7	.225	.67	10.4	26.8	0.87	.005	.034	.048	.853	112.5
Chile guaque (b)	*Capsicum annuum* var. *longum* (DC.) Sendt.	.....	Retalhuleu	91.4	0.14	1.7	.150	.57	11.6	20.1	0.50	.255	.058	.062	1.151	57.9
Chile jalapeño (a)	*Capsicum annuum* var. *longum* (DC.) Sendt.	.....	Zacapa	90.8	0.15	0.9	.248	.63	7.6	28.0	0.63	.065	.059	.038	1.254	65.0
Chile jalapeño (b)	*Capsicum annuum* var. *longum* (DC.) Sendt.	.....	Zacapa	90.8	1.01	1.7	.258	.63	5.7	31.6	0.45	.....	.095	.038	1.346	46.3
Chile jalapeño (c)	*Capsicum annuum* var. *longum* (DC.) Sendt.	.....	Zacapa	88.6	0.15	1.3	.258	.77	9.5	32.3	0.56	.482	.072	.121	1.836	76.5
Chile Japonés	*Capsicum pubescens* Ruiz and Pavón	.....	San Juan Sacatepéquez	90.0	0.22	1.1	.189	.49	5.1	19.7	0.94	.249	.051	.070	1.900	40.0
Chile pacaya	*Capsicum frutescens* var. *baccatum* (L.) Irish	.....	Mazatenango	79.7	2.36	6.4	.502	1.34	45.1	97.6	1.20	.133	.165	.102	3.085	38.7
Chile verde (a)	*Capsicum annuum* var. *longum* (DC.) Sendt.	.....	San Cristóbal	89.6	1.15	2.4	.326	.63	10.4	32.7	0.81	.534	.089	.062	1.909	99.2
Chile verde (b)	*Capsicum annuum* var. *longum* (DC.) Sendt.	.....	San Sebastián	89.6	0.35	3.2	.302	.68	12.0	38.7	0.56	.067	.127	.052	1.247	50.8
Güicoy (a)	*Cucurbita Pepo* L.	Squash	Mixco	91.1	0.12	0.3	.203	.65	23.8	32.8	1.66	.047	.049	.045	.508	27.3

Güicoy (b)	*Cucurbita Pepo* L.	Squash	Antigua	92.9	0.17	0.5	.121	.72	15.8	20.6	0.73	.057	.044	.022	.476	28.8
Güicoy (c)	*Cucurbita Pepo* L.	Squash	Comalapa	93.6	0.21	0.9	.169	.77	16.5	9.3	0.50	.144	.073	.020	.706	8.9
Güicoy (d)	*Cucurbita Pepo* L.	Squash	Villa Nueva	92.4	0.14	0.9	.216	.97	12.2	10.1	0.67	1.965	.056	.029	.688	6.2
Güicoy (e)	*Cucurbita Pepo* L.	Squash	Santiago Sacatepéquez	86.4	0.19	1.2	.339	.75	15.7	54.6	0.63	.093	.117	.062	.858	30.4
Güisquil (a)	*Sechium edule* (Jacq.) Sw.	Chayote	Paleneia	89.8	0.15	0.6	.180	.44	8.4	24.1	0.53	.001	.021	.035	.492	19.8
Güisquil (b)	*Sechium edule* (Jacq.) Sw.	Chayote	San Felipe	92.6	0.46	0.5	.099	.30	11.8	15.8	0.41	.000	.017	.026	.464	9.2
Güisquil (c)	*Sechium edule* (Jacq.) Sw.	Chayote	San Cristóbal	89.6	0.17	0.4	.271	.54	5.1	42.4	0.91	.014	.025	.046	.794	21.9
Güisquil perulera (d)	*Sechium edule* (Jacq.) Sw.	Chayote	San Bartolo	88.3	0.16	0.7	.191	.58	13.4	51.5	0.39	.019	.029	.048	.464	23.7
Miltomate (a)	*Physalis pubescens* L.	.....	Antigua	90.5	0.71	1.5	.236	.69	5.5	26.3	1.24	.026	.079	.036	3.280	6.8
Miltomate (b)	*Physalis pubescens* L.	.....	Rabinal	82.9	0.10	5.3	.395	1.15	15.4	48.8	1.03	.115	.077	.062	6.770	11.6
Pepino (a)	*Cucumis sativus* L.	Cucumber	Bárcenas	95.2	0.14	0.4	.134	.36	7.0	23.8	1.01	.002	.016	.025	.227	16.0
Pepino (b)	*Cucumis sativus* L.	Cucumber	Mixco	96.7	0.08	0.5	.127	.40	12.8	23.5	0.28	.020	.033	.021	.139	10.7
Pepino (c)	*Solanum muricatum* Ait.	Melon pear	Antigua	91.7	0.32	1.0	.085	.30	4.0	16.6	0.58	.003	.057	.044	.400	60.0
Pepino (d)	*Solanum muricatum* Ait.	Melon pear	Panajachel	90.2	0.32	0.5	.079	.29	3.5	17.4	0.32	.003	.058	.043	.344	34.6
Pepino (e)	*Solanum muricatum* Ait.	Melon pear	Atitlán	92.1	0.00	0.2	.050	.25	3.4	17.0	0.28	.136	.052	.037	.280	53.8
Perulera (a)	*Sechium edule* (Jacq.) Sw.	Chayote	Santa María	89.3	0.12	0.7	.156	.40	6.1	22.6	0.39	.007	.020	.031	.463	36.9
Perulera (b)	*Sechium edule* (Jacq.) Sw.	Chayote	La Labor de Castillo	92.0	0.09	0.6	.142	.38	11.4	23.0	0.35	.006	.030	.035	.411	20.4
Pimienta	*Capsicum annuum* var. *grossum* (L.) Sendt.	Sweet green pepper	Gualán	92.3	0.22	0.9	.172	.47	6.0	23.1	0.61	.080	.040	.023	.580	123.6
Tomate (a)	*Lycopersicum esculentum* (L.) Mill.	Tomato	Zacapa	93.7	0.49	0.8	.211	.56	4.4	20.8	0.67	.231	.062	.036	.547	19.2
Tomate (b)	*Lycopersicum esculentum* (L.) Mill.	Tomato	Mazatenango	91.7	0.60	1.2	.201	.62	9.7	28.5	1.08	.295	.073	.051	.587	26.3
Tomate (c)	*Lycopersicum esculentum* (L.) Mill.	Tomato	Bárcenas	93.7	0.12	0.9	.201	.50	8.8	24.7	0.32	.513	.064	.037	.613	24.7
Tomate extranjero	*Cyphomandra betacea* (Cav.) Sendt.	.....	Macote	87.8	0.08	1.4	.223	.84	11.3	13.1	0.72	.371	.038	.035	1.011	23.3
Tomatillo (a)	*Lycopersicum esculentum* var. *cerasiforme* Dunal	.....	Bárcenas	85.4	0.72	2.3	.323	1.03	20.2	37.9	0.93	.692	.143	.114	1.012	60.0
Tomatillo (b)	*Physalis aequata* Jacq.	.....	Mazatenango	90.6	0.32	1.7	.171	.69	10.9	27.9	0.57	.074	.093	.038	2.166	4.4
Tomatillo (c)	*Physalis pubescens* L.	.....	Antigua	90.3	0.65	1.6	.190	.56	4.8	24.9	0.57	.029	.085	.044	2.055	2.9

[1] Bárcenas is synonymous with Escuela Nacional de Agricultura.

Chipilín. There were three samples of this plant. All had a high content of calcium (398.3, 217.5, and 200.1 mg.), iron (7.86, 5.73, and 4.10 mg.), thiamine (0.394, 0.324, and 0.305 mg.), riboflavin (0.773, 0.570, and 0.411 mg.), niacin (2.765, 2.000, and 2.058 mg.), and ascorbic acid (133.0, 141.5, and 152.5 mg.). Two samples were also high in content of carotene (9.355 and 6.437 mg.). In other respects the samples showed remarkable uniformity in composition.

Espinaca. With the exception of content of iron (5.16 and 2.04 mg.) and carotene (0.057 and 2.640 mg.), the two samples of New Zealand Iceplant were very uniform in composition. Volcanic dust left on the leaves, even after washing, may account for differences in iron content. Both samples contained appreciable amounts of riboflavin (0.175 and 0.201 mg.).

Puntas de güisquil. Four samples of this plant were analyzed. They showed considerable variation in composition, especially in mineral and carotene content. Two samples gave high values for iron (8.17 and 3.82 mg.). All were significant sources of riboflavin (0.208, 0.172, 0.124, and 0.185 mg.) and niacin (1.190, 0.919, 1.023, and 1.018 mg.). The chayote grows as a dooryard plant, sometimes supported by trellises but more commonly on fences or over the house, and thus is an important food plant.

Flores de izote. Both samples of flowers of the yucca plant had a very high content of ascorbic acid (520.0 and 234.5 mg.). They also contained significant amounts of niacin (1.900 and 1.460 mg.).

Macuy. This common weed showed a high value for content of calcium (155.2 mg.), iron (10.71 mg.), riboflavin (0.345 mg.), and ascorbic acid (71.5 mg.).

Mostaza. Two samples of field mustard were analyzed. Both gave high values for calcium (170.8 and 191.5 mg.) and riboflavin (0.219 and 0.277 mg.). One gave a high value for iron (4.14 mg.) and contained significant amounts of carotene (1.025 mg.) and ascorbic acid (71.5 mg.); the other contained a smaller but significant amount of iron (1.51 mg.) and gave high values for content of carotene (4.198 mg.) and ascorbic acid (139.5 mg.). Both samples contained significant amounts of niacin (1.031 and 0.973 mg.).

Pacaya. The flowers of the palm were very high in content of calcium (421.6 mg.).

Aguacate and *Aguacatillo.* Six samples of avocado were analyzed. There was considerable variation among samples in values for ether extract (13.30, 18.59, 17.19, 7.03, 19.80, and 6.45 gm.). All contained significant amounts of niacin (1.575, 1.239, 1.773, 2.035, 1.627, and 1.258 mg.).

Chile. The 13 samples of peppers represented two species and four varieties of one species. With the exception of two, *chile chamborote* and *pimienta,* which had a mild flavor, all were "hot." The significantly high values are for niacin (ranging from 1.151 to 3.085 mg.) and for ascorbic acid (ranging from 38.7 to 176.7 mg.). One sample, *chile chamborote,* had a high content of carotene (2.360 mg.).

Miltomate and *Tomatillo* (c). The three samples of this common fruit showed exceptionally high values for content of niacin (3.280, 6.770, and 2.055 mg.).

Tomatillo (b). This fruit, like *miltomate* and *tomatillo* (c) of the same genus, shows a relatively high content of niacin (2.166 mg.).

SUMMARY

Data are presented for 124 samples of vegetables collected in Guatemala during a period from January, 1947, through June, 1948, and analyzed for content of moisture, ether extract, crude fiber, nitrogen, ash, calcium, phosphorus, iron, carotene, thiamine, riboflavin, niacin, and ascorbic acid.

Foods having a relatively high value for one or more constituents are discussed from the standpoint of their actual or potential value in the diet.

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COMPOSITION OF FOOD PLANTS OF CENTRAL AMERICA. III. GUATEMALA

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This report is the third in a series covering results from analyses of edible plants from the countries of Central America. Data from the analyses of 121 samples from Honduras were summarized in the first report, Munsell, Williams, Guild, Troescher, Nightingale, and Harris (1949), and of 124 samples from Guatemala in the second report, Munsell *et al.* (1950).

The 124 samples from Guatemala were of foods considered as vegetables. This paper deals with 106 additional samples collected in Guatemala during the same period and grouped as follows: 60 of fruits, two of cereals, 15 of legumes, and 29 of staple or dry foods, classified as cereals, legumes, fruits, or miscellaneous.

Information regarding collection and shipment of samples and methods of analysis has been given in the first two papers. No changes were made in these procedures. Areas where samples originated were essentially the same as for the 124 vegetables. Data relative to altitude, soil type, and rainfall in the specific areas concerned are given (Table 1).

The 106 samples included 52 different foods, there being more than one sample for 22 of these. The several samples of a food were usually taken in different areas.

DESCRIPTIONS AND USES OF FOODS STUDIED [1]

FRUITS; CITRUS:

Lima and *Limón*. The lime, sourest of the citrus fruits, is not much appreciated in Central America. When used, it is in soft drinks, as flavoring, or in preserves. One sample, *lima*, was purchased in the market; the other, *limón*, was obtained from an Indian. Both samples consisted of ripe fruits. Those of the first had pale-green juice, while those of the second had pale green-yellow skins and pale yellow-green juice. The juice in the samples analyzed was hand expressed.

Limón. See *Lima*.

Limón (I, Fruits, 4, *Limón*). These fruits are used chiefly by the "ladinos" or by Indians as a medicine for colds and other aches and pains. The sample comprised a number of small, round, ripe fruits with pale yellow-green skins. The juice had a greenish cast. Only the hand-expressed juice was analyzed.

[1] Descriptions of some of the foods have already been given in the first paper, Munsell *et al.* (1949a), or in the second paper, Munsell *et al.* (1949b), of this series. This is indicated by the notation in parenthesis following the name of the food and showing where the description is given.

TABLE 1

Information on Altitude, Prevailing Soil Type, and Approximate Average Annual Rainfall in Areas Where Samples Originated

Department	Town	Altitude	Soil	Rainfall [1]	No. of samples
		ft.	*Type*	*in.*	
Alta Verapaz	Cobán	4,200	Clay Loam	.....	7
Alta Verapaz	San Cristóbal	4,600	Clay Loam	.....	3
Alta Verapaz	San Pedro Carchá	4,200	Clay Loam	.....	5
Baja Verapaz	El Chol	3,000	.....	90	1
Chimaltenango	Comalapa	5,000-8,000	Volcanic	60-70	3
El Progreso	El Rancho	1,000	.....	50	1
El Progreso	Sanarate	2,000	Volcanic	50	2
Escuintla	Escuintla	1,000-2,200	Volcanic	60-70	7
Escuintla	Overo	1,000-2,000	Volcanic	60-70	2
Escuintla	San José	100	Silty loam outwash	70	1
Guatemala	Amatitlán	3,000	Volcanic	60	1
Guatemala	Bárcenas	4,800	Volcanic; loam	70	9
Guatemala	Boca del Monte	5,000	Volcanic	70	1
Guatemala	Chinautla	5,000	Volcanic	60	1
Guatemala	Guatemala	5,000	Volcanic	60-70	3
Guatemala	Jocotillo	4,500	Volcanic	60	1
Guatemala	Mixco	5,500	Volcanic	60-70	1
Guatemala	Palencia	6,000	Volcanic	60-70	1
Guatemala	Petapa	4,000-4,500	Volcanic	60-70	2
Guatemala	San Juan Sacatepéquez	7,000	Volcanic	60-70	1
Guatemala	San Pedro Ayúmpuc	3,000	Volcanic	50	2
Guatemala	San Pedro Sacatepéquez	6,000-6,600	Volcanic	60-70	3
Guatemala	Santa María	6,000-7,000	Volcanic	60	1
Guatemala	Villa Nueva	4,800	Volcanic	50-70	1
Jutiapa	Jutiapa	1,500	.....	40	1
Quezaltenango	Almolonga	7,400	Volcanic	70	2
Quezaltenango	Quezaltenango	7,600-8,000	Volcanic; loam	70	6
Quezaltenango	San Felipe	5,000	Volcanic	70	2
Retalhuleu	Retalhuleu	900	Probably volcanic	70	1
Sacatepéquez	Antigua	5,000-6,000	Volcanic	50-70	7
Sacatepéquez	San Bartolo	6,000-7,000	Volcanic	60-70	5
Sacatepéquez	San Juan del Obispo	7,000	Volcanic	70	1
Sacatepéquez	San Lucas	6,000-6,400	Volcanic	60	3
Sacatepéquez	San Pedro	6,000-7,000	Volcanic	70	1
Sacatepéquez	Santa Lucía	7,000	Volcanic	70	1
Sacatepéquez	Santa María de Jesús	7,000	Volcanic	70	1
Sacatepéquez	Santa María del Volcán de Agua	7,000	Volcanic	.....	1
Sacatepéquez	Santiago	6,300	Volcanic	60-70	1
Sacatepéquez	Santiago Sacatepéquez	6,000	Volcanic	70	1
Santa Rosa	Chiquimulilla	1,000	Outwash plain	.....	1
Sololá	Atitlán	4,800-6,000	Volcanic	70	3
Suchitepéquez	Mazatenango	1,300	Volcanic	70	4
Suchitepéquez	Santa Cecelia	1,500	Volcanic	70	1
Totonicapán	Momostenango	7,300-7,500	Volcanic	70	2
Zacapa	Zacapa	800	Volcanic	30-60	1

[1] Rainfall data for Guatemala, as for most other places in Central America, are scanty. Most of those given are estimates based largely on vegetation and what that vegetation would need to develop.

Naranja. The sweet orange is grown commonly in Central America and the fruit is greatly appreciated. The inferior varieties grown until now in this area are being replaced slowly by better varieties. The oranges are eaten as a fruit out of hand or the juice is expressed. Fruits represented by Samples (a) and (c) are sometimes used in preserves. Fruits of Sample (a) were of the Valencia type sweet orange and were small. They were taken directly from trees. Fruits of Sample (b), purchased in the market, were of poor quality with many seeds. The juice was of good orange color. Sample (c) consisted of rather fine oranges of good size with thick, rough skin, deep orange-colored flesh, and many seeds. Sample (d) consisted of Navel or Bahia oranges. These were taken directly from trees. Slurries of all four samples were made from the hand-expressed juice only.

FRUITS; BANANAS:

Banano (I, Fruits, 5, *Banano*). Fruits of Sample (a) were of the Gros Michel variety, the variety commonly exported to the United States. These are eaten as a fruit out of hand, or are boiled or baked. Subsamples were prepared from mashed, peeled whole fruits. Fruits of Samples (b), (c), and (d) were finger bananas having thin skins and rather dry flesh. These are eaten as a fruit out of hand or they may be cooked. All fruits were ripe. Transverse sections of 12 fruits were used in the subsamples of Sample (b); for Samples (c) and (d) whole, peeled fruits were mashed and mixed.

Plátano (I, Fruits, 5, *Plátano*). Samples (a), (b), and (c) of the plantains represent varieties that are eaten raw, as a fruit out of hand, or cooked. Fruits represented by Sample (d) are eaten only after cooking. Fruits of Sample (a) were mature and had pink flesh; those of Sample (b), members of the Rubra Race, were ripe. Fruits of Samples (c) and (d) were large with pale-yellow flesh, those of Sample (c) having moist flesh, and of Sample (d) dry flesh. Subsamples of Sample (c) were prepared from sections of peeled fruits; the other three samples were prepared by mashing and mixing whole, peeled fruits. All samples were purchased in the market.

FRUITS; NOT CLASSIFIED:

Ama uva. This grape is native to Central America and is quite common in some sections. Most of the fruit on the market comes from wild vines. It is eaten out of hand or used for jelly and for vinegar. The sample was purchased in the market and consisted of ripe fruits having purple skins and purple-green flesh. Whole fruits were used in the prepared sample.

Anona. The custard-apple, or Bullock's heart, is native to the West Indies and is naturalized and cultivated in much of Central America. The fruits have a sweet, white pulp, sometimes granular toward the rind. They are eaten as a fruit out of hand or used in ice cream and conserves. They are apt to vary considerably in quality. The sample was purchased in the market and consisted of fine-flavored, ripe fruits. The flesh only was used in the subsamples.

Azerola. The small tree or shrub producing this fruit is native to tropical America, where it is widely distributed and is sometimes found

under cultivation. The fruits are small with red skins and white to reddish flesh. They are eaten as a fruit out of hand. The sample was purchased in the market and the skin and flesh only were used in the stabilized samples.

Caimito. The star-apple tree is probably indigenous to the West Indies and is cultivated and has become naturalized in many places in Central America. The tree is one of the most handsome ornamental trees of the tropics. The fruits are variable in size and quality and the good ones are among the better of the tropical fruits, although a liking for them has to be acquired. They may be eaten out of hand or used in preserves. The sample was purchased in the market. The fruits had thick, purplish skin and white flesh grading to purple toward the skin. Mixed skin and flesh were used in the prepared sample.

Cereza. The wild cherry is native to Mexico and possibly also to western Guatemala. In some localities of western Guatemala it is exceedingly abundant and is cultivated and has become naturalized around Antigua. In season the fruits are common in most highland markets. They have a flavor similar to that of the common chokecherry and may be eaten as a fruit out of hand, stewed, made into preserves, or used to prepare a fermented drink. The sample, purchased in the market, consisted of ripe fruits having purplish-brown skins and green flesh. The expressed juice and pulp were used in the prepared sample.

Chico (I, Fruits, 6, *Níspero*). These fruits are generally eaten as fresh fruits but may be made into preserves. The sample was obtained in the market and consisted of a number of small, ripe fruits. The prepared samples were made from the mashed flesh after the fruits were peeled and the seeds removed.

Ciruela. Cultivated plums are now being introduced into Guatemala and are cultivated to some extent in the highlands. The supply of fruits of good quality in the markets is limited and the price is accordingly high. The flavor of the fruit grown in Guatemala is as good or better than that of fruit grown in the United States. They are eaten mainly as a fruit out of hand, but may be stewed or used in jams. The three samples were purchased in markets. Sample (a) consisted of good-sized, ripe fruits having dark-maroon skins and yellowish-red flesh; Sample (b) of ripe fruits with pale, clear-yellow skins and flesh; and Sample (c) of ripe fruits with maroon to pinkish-yellow flesh (red plums). Skin and flesh were included in the prepared samples.

Durazno. Peaches grown in Central America are small and of poor quality. Those of Guatemala may be better than the average. The best varieties are found in Guatemala. Fruits are never left to ripen on the tree, because of tendency to spoil. This fruit may be eaten as fresh fruit, stewed, or in preserves. The sample was purchased in the market from an Indian and consisted of ripe fruits of the clingstone type. The fruits were of poor quality and had white or pale-green flesh. For the prepared samples longitudinal wedges of peeled fruits were taken.

Granada. The pomegranate is not common in Central America although it is not difficult to grow there. It is eaten as a fruit out of hand. The

sample consisted of six large, ripe fruits purchased in the market. The juice, expressed by hand, was used in the prepared sample.

Granadilla. There are some 350 species of the genus *Passiflora*, of which only a few have value as food plants. The sweet granadilla is the one commonly seen in markets of Central America. It is found native in many areas and is also commonly cultivated. The fruit is eaten ordinarily as a fruit out of hand, but may be used as an ingredient of a cooling drink. The samples consisted of ripe fruits and the prepared samples were made from the pulp, juice, and seeds.

Guayaba. The guava is native to Central America. The fruits of both the wild and cultivated trees are exceedingly variable in form, color, and flavor. The wild plant is a small shrub, but under cultivation may grow to the size of a small tree. The ripe fruits may be eaten as a fruit out of hand or used in compotes and preserves. The sample, obtained in the market, was made up of ripe fruits having green skins and pink flesh. Flesh, skin, and seeds were included in the prepared samples.

Higo. The fig is not widely grown in Central America and the fruits are seldom allowed to ripen. It is used stewed for desserts, cooked with syrup as a *dulce*, and for candies. The sample was purchased in the market and consisted of unripe fruits with green skins and whitish flesh. Whole fruits, from which the hard stems had been cut, were used in the prepared samples.

Injerto. The sapote is native to Central America and is distributed over at least a part of this area because of its value as a fruit. When woodland is cleared, these trees are generally left. The fruit usually is eaten as a fruit out of hand or as a paste. It may be used in preserves or for a sweet. The samples were purchased in the market and all fruits were ripe. Fruits of Sample (a) had green skins and orange-brown to brown flesh; those of Sample (b) had orange-green skins and orange-red flesh; and of Sample (c) yellowish-red flesh. Flesh only was used in the prepared samples.

Jocote. The Spanish plum is probably native to Central America; if not, it has been naturalized. It is much appreciated and is found in most markets in season. There are many varieties, as most or all fruit comes from seedling trees and the fruits show considerable variation in quality and color. Good ones have an agreeable flavor. They are eaten as a fruit out of hand from the time they are green until they are quite ripe. They may also be used in preserves, for cooling drinks, or stewed, or dried. Samples were purchased in the market. Both samples consisted of ripe fruits, those of Sample (a) having orange to red skin and of Sample (b) golden yellow. Subsamples of Sample (a) included skin and pulp and of Sample (b) flesh only. Fruits of Sample (b) were washed and superficially dried.

Mamey, mamé. The mamey, or mamee apple, is a native of the Atlantic coast of Central America or has been naturalized there. The tree is very handsome and is used as a shade tree in some cities. The fruit is much appreciated and is distributed to markets outside the area of production. The skin of the fruit is russet-brown in color and often rough. It is leathery and easily peeled away from the flesh which is bright yellow or of

apricot color and resembles the apricot in flavor when cooked. The fruits are produced largely from seedling trees and accordingly vary in quality. They are eaten as a fruit out of hand or used in preserves. The samples were obtained in the market and the prepared samples were made from the flesh only. The flesh was orange or golden-yellow.

Mango (I, Fruits, 2, *Mango*). All samples of mangoes were obtained in the market except Sample (d), which was collected directly from trees. All fruits of the several samples were ripe but varied considerably in quality, color, and amount of fiber present. Fruits of Sample (a) represented one of the better varieties of mangoes. They had red skins, apricot-yellow flesh, little fiber, and were of fine flavor. Fruits of Sample (b), an early variety, were small and had little fiber. Sample (c) consisted of small fruits with yellow flesh, a variety that may be eaten green or ripe. Fruits of Sample (d) were of medium size with orange-yellow flesh; those of Sample (e) were small with green skins and golden-yellow flesh. Sample (f) consisted of large fruits with reddish skins, apricot-colored flesh with little fiber. Subsamples of all samples were made from the flesh only.

Manzana (I, Fruits, 1, *Perote*). Apples are grown more commonly in Guatemala than in other countries of Central America. Most of the trees are seedlings and the fruit produced is inferior. The apples may be eaten as a fruit out of hand or cooked. The samples consisted of small apples. Those of Sample (a) were hard and had green skins and pale-green flesh. Those of Sample (b) were unripe and rather sour.

Manzanilla. This fruit is in common cultivation in the mountain areas of Guatemala. It is either native there or has become so completely naturalized that it cannot be distinguished from a native plant. In season the fruit is found in large quantities in the markets and is a conspicuous item in the diet. It is eaten as a fruit out of hand or used in desserts, in preserves, and in other ways. The sample was obtained in the market and consisted of a number of fruits having orange-yellow skins and pale-yellow flesh. The prepared samples were made from flesh only.

Membrillo (I, Fruits, 1, *Membrillo*). Quinces may be eaten raw as a fruit out of hand, or cooked, or used in preserves. Fruits of the sample were purchased in the market and came from grafted trees. They were ripe but firm and had white flesh with a yellowish tinge. Flesh only was used in the prepared samples.

Nance. The small tree or shrub producing this fruit is widely distributed in tropical America and occasionally is cultivated. The fruits vary in quality, some being very poor and others quite good. In season they are found in large quantities in the markets and are relatively cheap. They are eaten as a fruit out of hand or used in preserves, for a cooling drink, or fermented and distilled into a rum-like liquor. The sample consisted of about 1,000 ripe fruits. Peel and pulp were used in the prepared samples.

Papaya. The papaya is undoubtedly native to the Americas and probably grew in most tropical areas long before their discovery. A plant that grows so readily and produces such fine fruit may easily have been carried over the whole area by man or disseminated by animals and birds. It springs up spontaneously around buildings or in the edges of clearings,

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especially in regions with moderate to heavy rainfall. The fruits vary considerably in quality. When ripe they are eaten as fresh fruit, used in preserves, or cooked. Green papayas may be cooked as a vegetable or in other ways. A very nice pie may be made from them. Sample (a) consisted of ripened fruits with pale-salmon flesh and of good flavor. Fruits of Sample (b) had yellow-red or yellow flesh and were also of good flavor. Prepared samples were made from longitudinal wedges taken from peeled fruits after removing the seeds.

Pataste. The plant is native from Mexico to northern South America and also is naturalized and cultivated. It is commonly planted in some places as shade for coffee. The aril surrounding the seeds is the part eaten, usually as a fruit out of hand. Seeds are used to make chocolate and are sometimes mixed with cacao seeds when sold.

Pera. In Central America pears are not found to any extent except in Guatemala and there only two varieties have been noted. These are grown principally in the Departments of Quezaltenango and Sacatepéquez and are abundant in the markets from May to July. The fruits are generally hard and have little flavor. They are seldom left to ripen, as they spoil rapidly. They may be eaten raw but are generally stewed. Samples (a) and (c) were obtained from Indians who grew them, and Sample (b) was purchased in the market. Fruits of Sample (a) were just under-ripe, of medium quality and fairly sweet, but contained rather large stone cells; those of Sample (c) were also under-ripe but had somewhat better flavor than fruits of Sample (a). Sample (b) represented an elongated variety. The fruits were under-ripe, hard, and full of stone cells. All prepared samples were made with flesh only.

Piña (I, Fruits, 6, *Piña*). Pineapples may be used as a fresh fruit or in preserves. The samples were obtained in markets. Sample (a) consisted of vine-ripe fruits of medium size with quite yellow flesh. Fruits of Sample (b) were large, ripe, juicy, and sweet, and had white flesh tinged with pale yellow. This is known as a white variety. Fruits of Sample (c) were vine-ripened. They were large, very juicy, and had pale-yellow flesh. Fruits of Sample (d) were ripe and although they seemed to be of poor variety were very juicy, sweet, and of fine flavor. The flesh was whitish. Flesh only was used for all prepared samples.

Pitahaya. This fruit is probably native to Guatemala where it is abundant in some areas. The fruit enjoys a rather wide market. It is perhaps one of the most colorful and beautiful of tropical fruits. The calyx covering the fruit is bright-red when ripe and the pulp is a bright, clear cerise with black seeds. The flavor is bland and faintly acid, but rather pleasing. The fruits are expensive. Ripe fruits, purchased in the market, made up the sample. Flesh and small seeds were used in the prepared samples.

Tuna. The prickly pear was probably brought from Mexico to Guatemala in colonial days as a host to the cochineal insect. Fruits are seen occasionally in the market. They are eaten as a fruit out of hand or used to make a candy. The sample was purchased in the market and consisted of ripe fruits. The pulp, with most of the seeds removed, was used in the prepared sample.

CEREALS:

Elote (I, Herbage Vegetables, *Jilote*). Sample (a) was a yellow variety of corn in the late milk stage; Sample (b) was a white variety just past the milk stage. Corn at this stage may be eaten as green corn or used for tamales and tortillas. Both samples were purchased in the market. For subsampling kernels were cut from the cob and mixed.

LEGUMES:

Alverja. In Central America peas are grown successfully only at high altitudes and are found most commonly in Guatemala and Costa Rica. They are used as a boiled vegetable. Samples (a) and (b) were obtained in the market. Sample (a) was fresh and of very good quality. Sample (c) was purchased from an Indian and the peas were very young and tender. After shelling they were washed and wiped dry before subsampling.

Ejote (I, Legumes, *Habichuela*). Snap or string beans are used in Guatemala as a boiled vegetable, in soups or stews, and sometimes in salads. Samples (a), (c), (d), (e), and (f) were purchased in the market; Sample (b) was taken from growing plants. Sample (d) consisted of a mixture of wax and green beans, about 60 and 40 per cent, respectively, and Sample (f) entirely of wax beans; the other samples were all of green string beans. Portions for the slurries of Samples (a), (e), and (f) consisted of whole pods. Samples (b), (c), and (d) were chopped and mixed before taking subsamples. Pods of Samples (c) and (d) were washed.

Frijol negro (I, Legumes, *Habichuela*). The sample was purchased in the market and consisted of shell beans that were mature but not dry. These beans are used in the same way as dry beans. The beans were washed and superficially dried before subsamples were prepared.

Gandul (I, Legumes, *Gandul*). The pigeon pea is not used in Guatemala and is not available in the markets. The sample was taken from plants growing in an experimental plot. Seeds used in the subsample were at the proper stage to eat.

Haba. In some highland areas of Guatemala the broad bean is cultivated extensively and is of considerable importance in the dietary of the Indians; it is not eaten to any extent by peoples of European extraction. The green shell beans are used as a boiled vegetable, in soups, in salads, in tamales, or fried in lard or butter. The mature dry beans may be used like other beans and are sometimes roasted and eaten like nuts. All samples were obtained in the market and consisted of shelled green seeds. The seed-coat, or aril, was removed before subsamples were prepared.

Piloy. The scarlet runner bean is apparently native in the region from Mexico to Panama and is cultivated over much of this area. Beans of this species are an important item in the diet of those peoples living in the highlands of Guatemala, especially in the western highlands. Color forms are varied. In some areas beans of different colors are mixed together, while in others they may be well separated. They may be used as green or dry shelled beans. The sample was purchased from an Indian and was taken from a variegated lot of fresh, shelled beans. These were washed and superficially dried before being subsampled.

DRY SAMPLES

CEREALS:

Arroz. In Central America rice is secondary to maize as a cereal. Both paddy and hill rice are grown, but the latter is by far the more common. Even so, the area devoted to the cultivation of rice is not large.

Maíz (I, Herbage Vegetables, *Jilote*). Samples (a) and (b) of shelled corn represent miscellaneous varieties purchased in the market and used chiefly in tortillas. Samples (c) to (f) are new varieties being grown at the Escuela Nacional de Agricultura and are not commonly in cultivation at present.

LEGUMES:

Frijol (I, Legumes, *Habichuela*). The several samples of beans analyzed included a number of varieties. Those represented by Samples (a), (c), and (e) are not common. Sample (b) consisted of the long, red kidney bean grown by Indians principally for sale and used mostly by the "ladinos" as a boiled bean. Samples (g), (h), and (i) are representative of the common black bean, the type represented by Sample (g) being the one used most commonly in San Pedro Carchá. The beans of Sample (i) are of the variety commonly grown and used by the Indians in many parts of Guatemala but especially around San Pedro Sacatepéquez. The red bean, Sample (f), is the second most commonly used variety. All samples were purchased in the market with the exception of Sample (h), which was obtained from the Indian who grew it.

Gandul (I, Legumes, *Gandul*). The pigeon pea is at present an experimental crop in Guatemala. The high nutritive value, indicated by results obtained from analyses of samples supplied for this study, created an interest in increasing production of green pods for consumption at the Escuela Nacional de Agricultura. The plant is being propagated as a possible source of food in the dry season. It is also an excellent cover crop.

Garbanzo. Cultivation of the chick-pea in Central America is not extensive, although it is found in most markets. The chick-pea is commonly used to thicken soups and also as a cooked food. The sample was purchased in the market.

Haba (this report, Legumes, *Haba*). Seeds of the broad bean may be roasted and eaten like nuts, or boiled. At best, they are not a delectable food.

Lenteja. Lentils are not commonly grown in Central America. They are used to a limited extent in soups, in stews, in salads, and as a cooked vegetable. The sample was obtained in the market.

Soya. Soybeans are not common in Central America but are being grown experimentally at the Escuela Nacional de Agricultura in Bárcenas, where they are used for human consumption, as well as for feed for stock.

FRUITS; BERRIES:

Café. Coffee is produced in all republics of Central America and is an important source of national income. Most, if not all, of that grown is of the species *C. arabica* L. Coffee grows well from about sea level up to an elevation of 6,000 feet, but that grown toward the upper limit of this range is generally considered to be the best. In Central America coffee is

an important adjunct to the meal and the fine art of properly preparing the beverage is practiced even in the humblest home. The sample, purchased in the Antigua market, was produced at middle elevations and was a fairly good grade of coffee. Coffee grown in the region of Antigua has a good reputation. Unroasted seeds of the sample were almost light blue in color.

Chile cobanera. This is the famous *chile de Cobán,* which is marketed throughout Guatemala. It may be a cultigen originating around Cobán and adapted to growing conditions there. It is sun dried and very hot and is used as flavoring. The sample was obtained near Cobán from an Indian who grew it, and consisted of small, red fruits, ovoid and broad in shape.

Chile guaque (II, Fruit Vegetables, *Chile guaque*). This pepper is grown commonly in the highlands around Guatemala City. The seeds are removed and the flesh used as a condiment.

FRUITS; GOURDS:

Ayote, pepita de (I, Fruit Vegetables, *Ayote*). The inner portion of the seeds of pumpkins and squashes is eaten by peoples of Central America. Salt, pepper, and sometimes chile pepper may be added for flavoring. Seeds may or may not be roasted. In some markets, the edible portion may be purchased already roasted and salted. The sample consisted of unroasted, unsalted seeds (edible portion) and was purchased in the market.

Chilacayote, pepita de (this report, *Ayote, pepita de*). This species of *Cucurbita* may be of American origin but it is rarely cultivated in Central America. When available the seeds are eaten the same as *pepita de ayote.* The sample was purchased from an Indian in the market.

MISCELLANEOUS:

Girasol. The common sunflower is not commonly cultivated in Central America and the seeds are not used as food for man to any great extent. When grown it is used chiefly as chicken feed or as a source of oil, although it may be eaten raw or roasted, or ground and put into tortillas. The sample was obtained at the Escuela Nacional de Agricultura.

Laurel. This tree belongs to the family *Lauraceae* and is native to Central America. Both green and dried leaves of the tree are found in the markets. They are used extensively, whole or ground, as flavoring in soups and stews or with meat. Those for the sample were air dried. Another species, *L. glaucescens* HBK., is also used as food and seems not to be distinguished by the local peoples from *L. guatemalensis* Mez.

Rosa de Jamaica (I, Herbage Vegetables, *Rosa de Jamaica*). The sample consisted of accrescent calyces, only, of roselle. These are used to make a cooling drink by first boiling and then allowing the "tea" to cool. The sample was purchased in the market at a medicine stall.

RESULTS AND DISCUSSION

Data on the 106 samples of food analyzed are summarized (Table 2). Values given are for the amounts of the respective nutrients in 100 g. of the raw edible portion of the plant.

TABLE 2

Composition of Food Samples From Guatemala

Name of food sampled			Place sample originated[1]	Constituents measured and yields per 100 gm.												
Spanish	Scientific	English		Moisture	Ether extract	Crude fiber	Nitrogen	Ash	Calcium	Phosphorus	Iron	Carotene	Thiamine	Riboflavin	Niacin	Ascorbic Acid Total
	FRUITS			*gm.*	*gm.*	*gm.*	*gm.*	*gm.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*
	1. Citrus															
Lima	*Citrus aurantifolia* (Christm.) Swingle	Lime	Momostenango	93.5	0.11	0.0	.051	.25	4.5	9.3	0.19	.003	.028	.011	.252	30.0
Limón (a)	*Citrus aurantifolia* (Christm.) Swingle	Lime	Santa Lucía	89.9	.....	0.1	.081	.29	10.4	11.2	0.92	.005	.011	.018	.091	30.0
Limón (b)	*Citrus limonia* Osbeck	Lemon	San Pedro Carchá	91.6	0.00	0.0	.052	.21	8.5	7.0	.....	.021	.010	.010	.108	35.7
Naranja (a)	*Citrus sinensis* (L.) Osbeck	Orange	Bárcenas	87.6	0.00	0.0	.061	.43	5.5	19.0	0.95	.017	.036	.013	.131	79.6
Naranja (b)	*Citrus sinensis* (L.) Osbeck	Orange	Santa Cecelia	88.3	0.51	0.0	.058	.35	8.2	9.3	1.09	.015	.037	.015	.183	54.5
Naranja (c)	*Citrus sinensis* (L.) Osbeck	Orange	San Cristóbal	91.0	0.00	0.0	.073	.29	4.9	10.7	2.74	.028	.048	.014	.187	52.5
Naranja sin pepitas (d)	*Citrus sinensis* (L.) Osbeck	Navel orange	Antigua	88.3	0.56	0.0	.115	.32	4.0	11.7	1.42	.005	.060	.014	.172	41.7
	2. Bananas and Plantains															
	Bananas															
Banano (a)	*Musa paradisiaca* var. *sapientum* (L.) Kuntze	Banana	Cobán	73.8	0.23	0.4	.242	.80	6.2	18.1	1.50	.084	.026	.049	.878	11.7
Banano (b)	*Musa paradisiaca* var. *sapientum* (L.) Kuntze	Finger banana	Petapa	70.4	0.08	0.3	.278	.98	6.5	27.1	0.42	.042	.027	.067	.890	10.1
Guineo manzano (c)	*Musa paradisiaca* var. *sapientum* (L.) Kuntze	Finger banana	San Felipe	68.7	0.53	0.3	.299	.82	3.8	25.9	0.53	.010	.054	.062	1.012	18.2
Manzano (d)	*Musa paradisiaca* var. *sapientum* (L.) Kuntze	Finger banana	San Cristóbal	64.2	1.01	0.8	.268	.75	3.2	50.4	0.41	.033	.043	.024	1.050	36.4
	Plantains															
Guineo blanco (a)	*Musa paradisiaca* L.	Plantain	San Pedro Carchá	72.5	0.14	0.5	.173	.80	4.7	18.0	0.45	.681	.031	.043	.723	17.4
Guineo morado (b)	*Musa paradisiaca* L.	Plantain	San Felipe	76.8	0.37	0.3	.185	.82	9.7	15.5	0.46	.019	.026	.030	.560	7.8

Plátano (c)	*Musa paradisiaca* L.	Plantain	Overo	61.7	0.14	1.0	.186	.90	1.9	79.4	0.78	.142	.059	.048	.660	19.9
Plátano (d)	*Musa paradisiaca* L.	Plantain	Overo	65.7	0.03	0.7	.157	.97	6.2	41.3	0.37	.239	.063	.030	.559	18.9
	3. Other															
Ama uva	*Vitis tiliifolia* Humb. and Bonpl.	Wild grape	Guatemala City	87.3	0.71	2.4	.435	.81	30.4	38.0	3.37	.021	.049	.048	2.333	4.8
Anona	*Anona reticulata* L.	.....	Chinautla	75.6	0.10	0.9	.192	.50	17.6	14.7	1.14	.000	.094	.126	.640	15.0
Azerola	*Malphigia Glabra* L.	.....	Near Lago Amatitlán	83.6	0.18	0.9	.283	.82	8.2	37.5	1.11	.003	.040	.043	.464	14.9
Caimito	*Chrysophyllum Cainito* L.	.....	Escuintla	78.5	2.02	1.0	.183	.08	14.1	19.4	0.44	.004	.022	.019	1.293	4.6
Cereza	*Prunus Capuli* Cav.	Wild cherry	Santa María del Volcán de Agua	80.8	0.37	0.1	.105	.56	17.2	16.9	0.84	.005	.016	.018	.640	22.2
Chico	*Manilkara Zapotilla* (Jacq.) Gilly	Nispero	El Rancho	66.0	0.93	2.6	.077	.46	21.6	7.6	0.24	.001	.001	.008	.228	21.3
Ciruela (a)	*Prunus domestica* L.	Plum	Near Lago Atitlán	88.2	0.37	0.4	.109	.35	6.7	10.0	0.43	.011	.017	.031	.308	4.7
Ciruela clara (b)	*Prunus domestica* L.	Plum	San Lucas	90.8	0.24	0.5	.083	.35	6.5	21.9	0.28	.003	.022	.022	.364	3.4
Ciruela Santa Rosa (c)	*Prunus domestica* L.	Plum	Quezaltenango	88.6	0.04	0.4	.110	.30	7.8	13.9	0.44	.037	.028	.034	.352	5.5
Durazno	*Prunus persica* (L.) Sieb. and Zucc.	Peach	San Juan del Obispo	84.3	0.56	0.6	.091	.53	5.3	16.3	0.68	.002	.030	.025	.240	9.1
Granada	*Punica Granatum* L.	Pomegranate	Momostenango	86.4	0.43	0.0	.065	.36	0.9	9.4	0.66	.000	.003	.012	.180	4.2
Granadilla (a)	*Passiflora ligularis* L.	Sweet granadilla	Comalapa	69.9	3.17	5.6	.474	1.36	7.6	78.0	1.16	.000	.000	.103	1.813	13.4
Granadilla (b)	*Passiflora ligularis* L.	Sweet granadilla	San Pedro Carchá	76.5	1.50	3.2	.365	1.09	13.7	44.0	0.70	.001	.002	.117	1.490	20.0
Guayaba	*Psidium Guajava* L.	Guava	Antigua	77.9	0.56	7.2	.148	.65	10.7	27.3	0.68	.063	.047	.038	1.532	292.0
Higo	*Ficus Carica* L.	Fig	Comalapa	86.8	0.14	2.2	.337	.85	78.2	30.9	2.44	.013	.055	.053	.320	12.2
Injerto (a)	*Pouteria viridis* (Pitt.) Cronquist	.....	Guatemala City	66.2	0.24	1.8	.226	.93	19.2	25.5	0.94	.003	.005	.016	1.920	33.6
Injerto (b)	*Pouteria viridis* (Pitt.) Cronquist	.....	Mixco	65.6	0.23	2.2	.298	1.88	22.4	38.5	0.37	.099	.011	.039	2.628	37.0
Injerto (c)	*Pouteria viridis* (Pitt.) Cronquist	.....	Antigua	72.7	0.14	2.6	.324	.95	18.8	29.2	0.90	.061	.015	.034	1.809	33.3

TABLE 2 *(Continued)*

Composition of Food Samples From Guatemala

Name of food sampled			Place sample originated[1]	Constituents measured and yields per 100 gm.												
Spanish	Scientific	English		Moisture	Ether extract	Crude fiber	Nitrogen	Ash	Calcium	Phosphorus	Iron	Carotene	Thiamine	Riboflavin	Niacin	Ascorbic Acid-Total
				gm.	*gm.*	*gm.*	*gm.*	*gm.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*
Jocote (a)	*Spondias purpurea* L.	Spanish plum	Antigua	65.9	0.17	0.6	.261	1.09	20.8	55.7	1.17	.066	.103	.038	1.770	64.8
Jocote (b)	*Spondias purpurea* L.	Spanish plum	Boca del Monte	67.5	0.08	0.3	.096	.86	6.1	53.4	0.37	.089	.044	.030	.840	40.7
Mamey (a)	*Mammea americana* L.	Mamey	Escuintla	85.5	0.26	0.9	.112	.29	8.2	14.4	2.51	.150	.024	.042	.430	10.2
Mamey (mamé) (b)	*Mammea americana* L.	Mamey	Escuintla	87.3	0.91	0.8	.062	.17	4.0	8.7	0.24	.078	.015	.027	.330	12.0
Mango (a)	*Mangifera indica* L.	Mango	El Chol	83.1	0.03	0.7	.048	.31	10.7	5.5	0.21	.798	.024	.032	.242	64.4
Mango choleño (b)	*Mangifera indica* L.	Mango	Zacapa	86.7	0.22	0.6	.073	.37	7.0	8.6	0.55	.135	.020	.025	.220	114.0
Mango de mico (c)	*Mangifera indica* L.	Mango	Guatemala City	81.5	0.72	0.6	.064	.37	12.4	7.7	0.20	.098	.027	.035	.347	57.5
Mango de coche (d)	*Mangifera indica* L.	Mango	Escuintla	78.9	0.03	0.7	.113	.51	7.5	13.9	0.37	.515	.052	.068	.707	63.6
Mango (mateŭ) (e)	*Mangifera indica* L.	Mango	Mazatenango	80.0	0.46	0.7	.112	.52	10.5	16.2	0.43	.224	.042	.062	.774	77.7
Mango rosa (f)	*Mangifera indica* L.	Mango	Retalhuleu	82.1	0.04	0.7	.059	.33	6.1	6.9	0.40	1.349	.028	.039	.318	41.8
Manzana (a)	*Malus sylvestris* Mill.	Apple	Comalapa	86.5	0.30	0.9	.078	.31	1.4	7.7	0.45	.004	.022	.019	.193	3.5
Manzana (b)	*Malus sylvestris* Mill.	Apple	Quezaltenango	84.6	0.04	0.9	.033	.23	4.1	7.8	0.50	.010	.022	.021	.104	15.1
Manzanilla	*Crataegus pubescens* (HBK.) Steud.	.....	Santa María	76.1	0.24	2.0	.123	.72	74.4	12.7	1.64	.111	.002	.031	.300	93.1
Membrillo	*Cydonia oblonga* var. *maliformis* (Mill.) Schneid.	Quince	San Juan Sacatepéquez	83.2	0.05	1.9	.050	.49	3.3	13.3	0.36	.020	.019	.015	.213	14.9
Nance	*Byrsonima crassifolia* (L.) DC.	.....	Escuintla	83.2	0.21	5.8	.124	.63	23.0	12.6	0.78	.002	.009	.015	.327	95.0
Papaya (a)	*Carica Papaya* L.	Papaya	Escuintla	88.4	0.34	0.7	.076	.47	12.9	11.2	0.65	.045	.028	.026	.383	36.4
Papaya (b)	*Carica Papaya* L.	Papaya	Mazatenango	86.8	0.53	0.7	.074	.40	21.0	7.0	0.49	.006	.031	.032	.227	51.5
Pataste	*Theobroma bicolor* Humb. and Bonpl.	.....	Mazatenango	79.2	0.30	1.1	.449	1.24	5.9	41.0	0.74	.224	1.770	.150	3.145	21.4

Pera larga (a)	*Pyrus communis* L.	Pear	San Bartolo	83.6	0.49	1.2	.045	.27	7.0	8.4	0.36	.004	.017	.015	.247	2.9
Pera larga (b)	*Pyrus communis* L.	Pear	Quezaltenango	85.9	0.04	1.4	.035	.52	6.2	9.5	0.27	.005	.019	.019	.330	4.3
Pera redonda (c)	*Pyrus communis* L.	Pear	San Bartolo	84.2	0.27	0.8	.047	.24	3.8	8.8	0.98	.000	.019	.017	.107	6.2
Piña (a)	*Ananas comosus* (L.) Merrill	Pineapple	San Cristóbal	83.6	0.55	0.4	.087	.30	14.2	5.7	0.86	.049	.070	.026	.231	74.0
Piñn blanca (b)	*Ananas comosus* (L.) Merrill	Pineapple	Mazatenango	84.9	0.11	0.3	.081	.43	28.5	6.8	0.48	.002	.084	.033	.180	31.7
Piña de azúcar (c)	*Ananas comosus* (L.) Merrill	Pineapple	Jocotillo	87.0	0.10	0.4	.091	.36	5.8	5.7	1.24	.005	.059	.040	.240	31.0
Piña de azúcar (d)	*Ananas comosus* (L.) Merrill	Pineapple	Escuintla	84.7	0.27	0.3	.096	.44	37.2	9.4	0.28	.002	.080	.038	.208	33.0
Pitahaya	*Hylocereus undatus* (Haworth) Britt. and Rose	.....	Near Lago Atitlán	83.0	0.61	0.9	.229	.68	6.3	36.1	0.65	.005	.028	.043	.430	8.0
Tuna	*Noptalea cochenillifera* (L.) Salm. and Dyck.	Prickly pear	Atitlán	83.4	0.31	2.8	.208	.33	13.7	21.2	0.34	.002	.007	.034	.340	16.8
	CEREALS													
Elote (a)	*Zea Mays* L.	Green corn	Palencia	73.5	0.89	0.8	.625	.71	4.6	96.5	0.50	.004	.134	.100	2.060	15.8
Elote (b)	*Zea Mays* L.	Green corn	Petapa	69.3	1.21	0.9	.605	.76	3.0	105.6	0.53	.029	.172	.083	1.715	9.4
	LEGUMES													
Alverja (a)	*Pisum sativum* L.	Pea	San Bartolo	76.4	0.32	2.3	1.068	.78	24.3	94.2	2.23	.026	.346	.191	2.630	30.5
Alverja (b)	*Pisum sativum* L.	Pea	San Bartolo	72.7	0.62	3.0	1.218	.89	18.4	118.1	2.06	.009	.323	.159	2.190	18.5
Alverja (c)	*Pisum sativum* L.	Pea	Quezaltenango	79.7	0.21	2.2	.926	.74	22.7	92.1	1.58	.166	.310	.159	1.945	47.3
Ejotes (a)	*Phascolus vulgaris* L.	Green string beans	Antigua	88.5	0.22	1.5	.389	.76	45.8	49.8	1.11	.202	.087	.110	.670	12.9
Ejotes (b)	*Phascolus vulgaris* L.	Green string beans	Quezaltenango	92.5	0.22	0.7	.316	.57	45.1	43.3	1.24	.000	.044	.074	.533	22.4
Ejotes (c)	*Phascolus vulgaris* L.	Green string beans	Santa María de Jesús	90.5	0.20	1.1	.291	.69	77.8	35.8	0.70	.456	.054	.125	.402	4.0
Ejotes (d)	*Phascolus vulgaris* L.	Green string beans	Almolonga	91.3	0.03	1.2	.296	.54	37.1	35.6	0.82	.166	.063	.090	.474	23.2
Ejotes bayos (e)	*Phascolus vulgaris* L.	Green string beans	Santiago	89.6	0.19	1.3	.387	.79	38.4	48.8	0.87	.130	.077	.144	.560	35.6
Ejotes blancos (f)	*Phascolus vulgaris* L.	Green string beans	San Lucas	90.0	0.21	1.1	.340	.65	40.1	41.4	1.11	.012	.079	.087	.710	20.2

TABLE 2 *(Concluded)*

Composition of Food Samples From Guatemala

Name of food sampled			Place sample originated[1]	Constituents measured and yields per 100 gm.												
Spanish	Scientific	English		Moisture	Ether extract	Crude fiber	Nitrogen	Ash	Calcium	Phosphorus	Iron	Carotene	Thiamine	Riboflavin	Niacin	Ascorbic Acid-Total
				gm.	*gm.*	*gm.*	*gm.*	*gm.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*
Frijol negro	*Phaseolus vulgaris* L.	Black bean	Villa Nueva	53.4	0.31	3.6	1.569	1.88	77.8	168.0	3.62	.022	.361	.134	1.422	2.3
Gandul	*Cajanus Cajan* (L.) *Millsp.*	Pigeon pea	Bárcenas	67.6	0.38	2.5	1.146	1.26	32.2	132.9	1.88	.064	.318	.195	2.335	48.5
Haba (a)	*Vicia Faba* L.	Broad bean	San Lucas	74.2	0.19	3.1	1.128	.89	27.1	118.3	2.05	.018	.349	.161	1.740	29.9
Haba (b)	*Vicia Faba* L.	Broad bean	San Pedro	56.5	0.58	6.9	1.886	1.11	27.6	165.1	2.68	.127	.241	.203	2.050	16.5
Haba (c)	*Vicia Faba* L.	Broad bean	Almolonga	66.4	0.32	1.1	1.802	1.10	22.9	152.7	2.48	.120	.383	.180	2.114	21.7
Piloy	*Phaseolus coccineus* L.	Scarlet runner bean	Cobán	34.2	0.31	12.2	2.630	2.77	60.6	276.6	4.10	.034	.538	.138	2.270	0.2
		DRY FOODS														
		Cereals														
Arroz	*Oryza sativa L.*	Rice	Chiquimulilla	13.0	0.72	0.4	1.404	.34	5.8	87.3	0.97	.000	.083	.029	1.618	.....
Maíz (a)	*Zea Mays* L.	Maize	Sanarate	11.9	6.14	1.8	1.594	1.20	6.0	291.0	2.40	.022	.454	.081	2.330	.....
Maíz (b)	*Zea Mays* L.	Maize	Sanarate	12.8	5.56	1.6	1.335	1.30	5.7	299.8	1.91	.187	.369	.080	2.074	.....
Maíz (c)	*Zea Mays* L.	Maize	Bárcenas	13.3	5.03	1.5	1.404	1.36	3.6	309.0	2.11	.237	.508	.071	1.900	.....
Maíz (d)	*Zea Mays* L.	Maize	Bárcenas	11.5	4.77	1.5	1.440	1.34	4.1	313.0	2.76	.212	.511	.070	1.941	.....
Maíz (e)	*Zea Mays* L.	Maize	Bárcenas	12.3	4.78	1.7	1.483	1.34	4.9	303.0	2.42	.008	.582	.084	1.858	.....
Maíz (f)	*Zea Mays* L.	Maize	Bárcenas	12.2	3.90	1.4	1.527	1.42	5.2	316.0	2.81	.008	.585	.088	2.014	.....
		Legumes														
Frijol	*Phaseolus vulgaris* L.	Small red bean	San Pedro Carchá	6.9	1.91	4.8	3.950	3.85	121.3	436.0	6.25	.002	.468	.142	2.207	.....
Frijol bayo	*Phaseolus vulgaris* L.	Kidney bean, red	San Pedro Ayúmpue	9.4	1.51	4.6	3.760	3.58	98.6	399.4	5.64	.032	.521	.163	2.240	.....
Frijol bayo canaria	*Phaseolus vulgaris* L.	Kidney bean, yellow	Jutiapa	14.1	3.06	3.8	3.350	3.12	107.6	284.2	6.63	.019	.282	.157	1.794	.....
Frijol blanco	*Phaseolus vulgaris* L.	Navy bean	San Pedro Sacatepéquez	13.6	2.69	4.8	3.665	4.06	180.4	526.0	6.14	.020	.579	.148	1.859	.....
Frijol bolonillo	*Phaseolus vulgaris* L.	Black bean	San Pedro Ayúmpue	12.9	2.34	4.8	3.780	3.58	195.6	459.5	6.12	.042	.482	.146	2.124	.....

Frijol colorado	*Phascolus vulgaris* L.	Small red bean	San Pedro Sacatepéquez	14.8	2.49	4.3	3.680	3.98	99.2	518.5	5.66	.017	.467	.149	2.175	.....
Frijol negro	*Phascolus vulgaris* L.	Black bean	San Pedro Carchá	16.3	2.45	4.5	3.560	3.51	163.1	317.2	5.74	.022	.407	.155	1.942	.....
Frijol negro	*Phascolus vulgaris* L.	Black bean	Cobán	14.9	2.14	4.5	3.470	3.46	138.1	303.4	5.38	.020	.338	.149	1.725	.....
Frijol negro	*Phascolus vulgaris* L.	Black bean	San Pedro Sacatepéquez	9.1	1.68	4.7	3.495	3.66	119.8	370.8	6.38	.006	.562	.152	2.290	.....
Gandul	*Cajanus Cajan* (L.) Millsp.	Pigeon pea	Bárcenas	12.9	1.02	7.5	3.183	3.21	106.1	195.3	3.58	.066	.645	.140	1.933	.....
Garbanzo	*Cicer auriculinum* L.	Chick-pea	Antigua	8.9	5.53	3.8	3.095	2.33	115.9	269.4	8.29	.023	.341	.151	1.472	.....
Haba	*Vicia Faba* L.	Broad bean	Quezaltenango	8.9	2.15	9.5	4.090	3.00	122.4	386.2	25.75	.045	.348	.258	2.580	.....
Lenteja	*Lens culinaris* Medic.	Lentil	Antigua	14.7	2.13	4.0	3.890	2.03	77.5	365.0	10.69	.017	.391	.226	1.738	.....
Soya	*Glycine Max* (L.) Merrill	Soybean	Bárcenas	9.9	20.12	4.6	5.260	5.30	157.8	898.5	10.69	.012	1.181	.250	1.895	.....
	FRUITS															
	Berries															
Café	*Coffea arabica* L.	Coffee bean	Cobán	10.5	4.96	23.1	1.810	3.24	95.8	137.2	3.87	.019	.321	.068	1.108	.....
Chile cobanero	*Capsicum annuum* var. *cerasiforme* Irish	Chile	Cobán	4.7	28.75	13.6	1.770	7.80	134.8	370.2	7.98	14.140	.268	1.025	13.860	9.9
Chile guaques	*Capsicum annuum* var. *longum* (DC.) Sendt.	Pepper	Santiago Sacatepéquez	8.8	9.05	25.3	1.285	8.36	106.5	208.1	4.81	25.414	.140	1.293	7.340	13.6
	Gourds															
Ayote, pepita de	*Cucurbita Pepo* L.	Pumpkin seed	Cobán	4.6	50.50	1.5	5.930	4.66	47.9	1273.0	8.59	.090	.260	.286	1.990	.....
Chilacayote, pepita de	*Cucurbita maxima* Duchesne	Squash seed	Cobán	5.3	50.75	1.7	5.460	4.84	68.9	1329.0	8.67	.027	.251	.164	3.365	.....
	Miscellaneous															
Girasol	*Helianthus annuus* L.	Sunflower seed	Bárcenas	4.6	51.62	2.1	4.390	4.54	93.1	1065.0	7.25	.030	1.962	.232	5.850	.....
Laurel	*Litsea guatemalensis* Mez.		San Bartolo	8.0	7.01	23.7	2.190	4.92	803.0	113.6	15.04	9.479	.097	.649	2.465	.....
Rosa de Jamaica	*Hibiscus Sabadariffa* L.	Roselle	San José	9.2	2.61	12.0	1.146	6.90	1263.0	273.2	8.98	.029	.117	.277	3.765	6.7

[1] Bárcenas is synonymous with Escuela Nacional de Agricultura.

A number of these samples show relatively high values for some nutrients as indicated in the following discussion.

Bananas and *Plantains.* The several samples of these fruits contained fairly uniform amounts of most of the constituents measured. It is of interest that all contained significant amounts of niacin (ranging from 0.559 to 1.050 mg.).

Ama uva. This fruit is another one with a high value for content of niacin (2.333 mg.). The sample also contained a fair amount of iron (3.37 mg.).

Granadilla. The two samples of this fruit contained appreciable amounts of niacin (1.813 and 1.490 mg.).

Guayaba. In addition to a very high content of ascorbic acid (292.0 mg.), the sample of guava also contained an appreciable amount of niacin (1.532 mg.).

Injerto. The three samples of *sapote* contained relatively large amounts of niacin (2.628, 1.920, and 1.809 mg.).

Jocote. The niacin content of one sample of this fruit was relatively high (1.770 mg.), while that of the other was much less (0.840 mg.), although not insignificant. Both samples contained appreciable amounts of ascorbic acid (64.8 and 40.7 mg.).

Mango. The six samples of mango showed considerable variation in composition, especially in content of ascorbic acid (range 41.8 to 114.0 mg.).

Manzanilla. The one sample of this fruit contained a large amount of ascorbic acid (93.1 mg.). The fruit should probably be considered an important source of this nutrient.

Nance. The one sample of this fruit contained approximately the same amount (95.0 mg.) of ascorbic acid as the sample of manzanilla. It probably should be considered an important source of this constituent.

Pataste. This fruit is of interest because of the unusually high content of thiamine (1.770 mg.) and of niacin (3.145 mg.) in the aril surrounding the seed.

Piña. The four samples of pineapple varied in their content of several constituents and most significantly in content of ascorbic acid. One sample gave a relatively high value (74.0 mg.), while the other three samples contained less than half this amount (31.7, 31.0, and 33.0 mg.).

Elote. The two samples of green corn gave relatively high values for niacin content (2.060 and 1.715 mg.).

Shelled legumes—*alverja, frijol, gandul, haba,* and *piloy*—showed significantly high values for thiamine (0.241 to 0.538 mg.), riboflavin (0.134 to 0.203 mg.), and niacin (1.422 to 2.630 mg.). All had fair amounts of iron (1.58 to 4.10 mg.).

DRY SAMPLES

Arroz. Data on the one sample of rice give additional evidence that this cereal is a significant source of protein and niacin.

Maíz. Except for carotene content the six samples of corn showed remarkable uniformity in composition. The significantly high values were for thiamine (0.369 to 0.585 mg.) and niacin (1.858 to 2.330 mg.).

Legumes. As was to be expected, all samples of legumes showed a high content of nitrogen (3.095 to 5.260 g.), calcium (77.5 to 195.6 mg.), iron (3.58 to 25.75 mg.), thiamine (0.282 to 1.181 mg.), and niacin (1.472 to 2.580 mg.). *Haba, lenteja,* and *soya* also gave high values for riboflavin (0.258, 0.226, and 0.250 mg., respectively). *Soya* showed the highest values for nitrogen (5.260 g.) and thiamine (1.181 mg.); *frijol bolonillo,* the highest for calcium (195.6 mg.); and *haba,* the highest for iron (25.75 mg.), riboflavin (0.258 mg.), and niacin (2.580 mg.).

Café. The one sample of coffee contained significant amounts of nitrogen (1.810 g.), calcium (95.8 mg.), and niacin (1.108 mg.), and gave relatively high values for iron (3.87 mg.) and thiamine (0.321 mg.). The sample consisted of unroasted seeds and the composition of the beverage remains to be determined.

Chile. The two samples of chile represented two varieties of *Capsicum annuum.* They gave high values for ether extract (28.75 and 9.05 g.), nitrogen (1.770 and 1.285 g.), calcium (134.8 and 106.5 mg.), iron (7.98 and 4.81 mg.), carotene (14.140 and 25.414 mg.), thiamine (0.268 and 0.140 mg), riboflavin (1.025 and 1.293 mg.), and niacin (13.860 and 7.340 mg.). The way in which they are used would determine their value as sources of these nutrients in the diet.

Pepita de Ayote; Pepita de Chilacayote. Analysis of one sample each of pumpkin and of squash seeds indicates these seeds have a high content of ether extract (50.50 and 50.75 g.), nitrogen (5.930 and 5.460 g.), iron (8.59 and 8.67 mg.), thiamine (0.260 and 0.251 mg.), and niacin (1.990 and 3.365 mg.). The pumpkin seeds also gave a high value for riboflavin (0.286 mg.).

Girasol. The sunflower seeds gave high values for ether extract (51.62 g.), nitrogen (4.390 g.), iron (7.25 mg.), and riboflavin (0.232 mg.), and in this respect are similar to pumpkin seeds. They gave much higher values for thiamine (1.962 mg.) and niacin (5.850 mg.), however, than those given by pumpkin seeds. Although sunflower seeds are not used for human consumption to any extent, results of the analysis indicate their potential value as food.

Laurel. Leaves of this tree appear to be an outstanding source of calcium (803.0 mg.) and iron (15.04 mg.). The sample also gave high values for carotene (9.479 mg.), riboflavin (0.649 mg.), and niacin (2.465 mg.), and a significantly high value for nitrogen (2.190 g.). It can be an important source of all these nutrients.

Rosa de Jamaica. The sample of these flower parts gave an extraordinarily high value for content of calcium (1263.0 mg.) and high values for content of iron (8.98 mg.), riboflavin (0.277 mg.), and niacin (3.765 mg.). Their value as a source of these constituents depends, of course, upon the amounts extracted in the "tea" prepared from them.

SUMMARY

Results from analyses of 106 samples of edible food plants are presented. These samples included 60 of fruits, two of cereals, 15 of legumes, and 29 of staple foods (seven of cereals, 14 of legumes, five of fruits, and three miscellaneous). All were collected in Guatemala during January,

1947, through June, 1948. Analyses included determinations of moisture, ether extract, crude fiber, nitrogen, ash, calcium, phosphorus, iron, carotene, thiamine, riboflavin, niacin, and ascorbic acid.

Data on a number of samples indicated that many of the foods had a high content of one or more nutrients. These are discussed and the foods of particular interest considered.

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RETENTION OF RIBOFLAVIN IN VEGETABLES PRESERVED BY FREEZING[1]

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This study was undertaken to determine the effect of preparation for freezing, freezing, freezer storage, and subsequent cooking on the riboflavin content of peas, snap beans, soybeans, and spinach. The four vegetables were blanched and cooled according to procedures commonly employed in the home, and were frozen and stored under conditions approximating those maintained in many commercial locker plants. Retention of riboflavin in two varieties of peas and spinach, one variety of snap beans grown in two different years, and one variety of soybeans was investigated. Several studies concerning the effect of the above method of preservation and of cooking frozen vegetables, on the retention of riboflavin, have been reported in the literature.

Fellers, Esselen, and Fitzgerald (1940), using the rat growth method of assay, determined that fresh Thomas Laxton peas contained 210 μg. riboflavin per 100 gm. and the frozen ones, 220. Working with the same variety, Bedford, McGregor, and Wilcox (1944) reported values of .130, .089, .111, and .094 mg. riboflavin per 100 gm. for the raw, blanched, frozen, and frozen stored peas, respectively. Bedford, McGregor, and Watts (1945) found higher concentrations of riboflavin in Thomas Laxton peas grown during another season: .182 mg. per 100 gm. in the fresh, .137 after water-blanching, and .143 after five months of freezer storage. Although the amounts of riboflavin present in Thomas Laxton peas were decreased by blanching, Lee and Whitcombe (1945) observed no significant differences in vitamin contents due to the different types of potable water used for blanching. Lee, Gortner, and Whitcombe (1946) froze Thomas Laxton peas very slowly, at intermediate rates, and very rapidly, and found that the various rates of freezing did not affect amounts of riboflavin present. The only significant losses of riboflavin were caused by cooking the stored frozen peas in relatively large volumes of water. In an earlier study Johnston, Schauer, Rapaport, and Deuel (1943) reported riboflavin retentions of 64.8 and 70.5 per cent when frozen peas were cooked in pyrex and aluminum saucepans, respectively. Briant, Mackenzie, and Fenton (1946) found that from 70 to 91 per cent of riboflavin in frozen peas was retained in the vegetable after preparation for serving by quantity cooking methods.

Farrell and Fellers (1942) investigated effects of freezing, canning, and dehydration on the vitamin content of green snap beans. Raw, fresh Bountiful snap beans were found to contain 132 μg. riboflavin per 100 gm.,

[1] Work undertaken as part of the National Cooperative Experiment Station Project on "Conservation of Nutritive Values of Foods."

while blanched and frozen beans contained 156 μg. No loss occurred while cooking the frozen beans. Kelly, Wegner, and Mattson (1944) reported that amounts of riboflavin present in green snap beans were not appreciably decreased due to freezer locker storage. Bedford, McGregor, and Wilcox (1944) worked on two varieties of snap beans: Tendergreen, which contained .109 mg. per 100 gm., and Stringless Black Valentine, .117 mg. Losses in riboflavin content of these two varieties of beans, calculated on the wet basis, were 11.1 and 18.2 per cent after blanching, 1.7 and 9.3 per cent after blanching and freezing, and 9.3 and 9.3 per cent after blanching, freezing, and nine months of freezer storage, respectively. Phillips and Fenton (1945) found that Tendergreen snap beans, blanched two minutes in boiling water, lost 14 per cent of the riboflavin content. During chilling there was an additional loss of five per cent and no change occurred during freezing. Lee and Whitcombe (1945) reported that losses in blanching were not affected by using different potable waters. Phillips and Fenton (1945) cooked 300-gm. lots of frozen snap beans in 50 and 250 gm. water; percentage retentions of riboflavin in the beans were 86 and 72, respectively. Briant, Mackenzie, and Fenton (1946) reported that frozen snap beans retained from 64 to 85 per cent of the riboflavin content when cooked by three quantity methods.

Lee and Whitcombe (1944) stated that frozen soybeans of the Bansei, Giant Green, and Jogun varieties contained approximately 22 μg. riboflavin per avoirdupois ounce. Bedford, McGregor, and Wilcox (1944) obtained losses of 16.9 and 5.0 per cent of the amounts of riboflavin present in fresh Bansei soybeans after blanching, and after seven months of freezer storage, respectively. In a later study, Bedford, McGregor, and Watts (1945) found that Bansei soybeans lost 29 per cent of their riboflavin content during water-blanching prior to freezing.

Little work has been done on retention of riboflavin in frozen spinach. Fellers, Esselen, and Fitzgerald (1940) found that fresh and frozen Virginia Savoy spinach contained 436 and 330 μg. riboflavin per 100 gm., respectively. Gleim, Tressler, and Fenton (1944) reported that Heavy Pack spinach with an original riboflavin content of .213 mg. per 100 gm. lost 40 per cent, calculated on the dry weight basis, during commercial freezing procedures. Cooking the frozen spinach in a relatively large amount of water resulted in a greater decrease in riboflavin content than did cooking in a small amount of water in a covered pan.

EXPERIMENTAL PROCEDURE

Vegetables used in this study were grown under the supervision of the Department of Horticulture of the University of Illinois. They were harvested at suitable stages of maturity for freezing and brought to the food research laboratory for processing on the day they were picked. Dark Podded Thomas Laxton and Little Marvel peas were obtained from June 19 to 22, 1945, and from June 20 to 27, 1947, respectively; Asgrow Black Valentine snap beans, from August 20 to September 5, 1945, and from August 13 to 19, 1947; Giant Green soybeans, from September 16 to 19, 1946; and Bloomsdale Savoy Long Standing and Virginia Savoy (Blight Resistant) spinach, from May 28 to June 6, 1945, and from October 23

to November 1, 1945, respectively. Each vegetable was processed on four different days.

Preliminary Treatment: Peas were hulled, washed, and dried. Snap beans were washed, dried, the cap and stem-ends removed, and the beans cut crosswise in approximately one and one-half-inch pieces. Soybeans were washed and dried in the pods. Spinach was thoroughly washed, tough portions of the stems cut off and discarded, and leaves and tender stems allowed to drain, then shaken and partially dried on towels.

Blanching: Samples of peas, snap beans, and spinach, weighing 300, 240 and 450 gm., respectively, were tied up in single layers of cheesecloth so they were contained in loosely fitting bags. Details of the blanching procedures are given (Table 1). Blanching operations were repeated a

TABLE 1

Blanching Procedures Used for Vegetables

Vegetable and variety	Year	Bags blanched at one time	Wt. of vegetable in each bag	Amt. boiling water used for blanching	Length blanching period [1]	Temp. of water, at end of blanching period
Peas		*no.*	*gm.*	*qts.*	*min.*	
Dark Podded Thomas Laxton	1945	3	300	6	1	89°C.(192.2°F.)
Little Marvel	1947	3	300	6	1	92°C.(197.6°F.)
Snap Beans						
Asgrow Black Valentine	1945	5	240	8	3	94°C.(201.2°F.)
Asgrow Black Valentine	1947	5	240	8	3	95°C.(203.0°F.)
Soybeans [2]						
Giant Green	1946	....	.....	6	5	94°C.(201.2°F.)
Spinach						
Bloomsdale Savoy Long Standing	1945	2	450	8	1	91°C.(195.8°F.)
Virginia Savoy (Blight Resistant)	1945	2	450	8	1	90°C.(194.0°F.)

[1] Timed from instant vegetable was lowered into the boiling water. Heating was continued during the blanching period. [2] Soybeans were blanched and cooled before hulling, 1,800 gm. at one time.

sufficient number of times to provide samples for analysis after blanching, after blanching and cooling, after approximately 20 hours in the freezing unit, after freezer storage for one, three, six, and nine months, and in the cases of peas and snap beans, after cooking following freezer storage.

Subsequent Treatment: After blanching, the vegetables were immediately immersed in a kettle of cold water and, except for the soybeans, cooled three minutes in cold running water. The soybeans were cooled five minutes. Peas and snap beans were drained and the surface moisture removed with towels. Spinach was drained and the excess water pressed out. Soybeans were hulled, partially dried, and weighed out in 350-gm. lots. Each sample was packed in a cellophane-lined pint container which was then sealed with heat. The filled cartons were held in a refrigerator until the series of samples to be prepared that morning was completed. At that time they were taken to the freezing unit.

Freezing and Freezer Storage: The samples were placed in a freezing unit of the plate type and allowed to remain for approximately 20 hours. Temperature on the plates ranged from −24 to −30°C.(−11.2 to −22.0°F.). The containers were then transferred to freezer storage where the temperature was −17.8°C. ± 2.8°(0°F. ± 5.0°).

Cooking Frozen Peas and Snap Beans: Dark Podded Thomas Laxton and Little Marvel peas were cooked after six and nine months of freezer storage, respectively, and Asgrow Black Valentine snap beans, after three, six, and nine months of freezer storage. Samples of frozen peas and snap beans with mean weights of 287 and 235 gm., respectively, were placed in 100 ml. boiling salted water and cooked in two-quart aluminum pans with tightly fitting covers. Average time required for the water to return to boiling after addition of the peas was 4.7 minutes; then they were boiled five minutes. In the case of snap beans, the water returned to boiling in 4.3 minutes and the beans were boiled eight minutes. Regulation of the gas burners, control of the weights of water, amounts of salt used, and draining of the cooked products were carried out according to the mimeographed outline of Recommended Laboratory Procedures for Food Preparation and Food Preservation for the National Cooperative Experiment Station Project on "Conservation of Nutritive Values of Foods."

After each procedure the treated lots of vegetables were weighed. The raw and processed vegetables were sampled for riboflavin determinations, care being taken to secure representative portions of material. This was done at all stages except the riboflavin content of soybeans and spinach was not determined after blanching. Extracts were prepared and fluorometric determinations made according to the procedures outlined by Van Duyne, Chase, Owen, and Fanska (1948). Ten ml. of 2.5M CH_3COONa were added to the cooled, autoclaved extracts of Bloomsdale Savoy Long Standing spinach and of Dark Podded Thomas Laxton peas, instead of 12 ml. of 6.5 per cent $Na_3PO_4 \cdot 12H_2O$ and two ml. of glacial CH_3COOH, which were added to the other extracts.

RESULTS AND DISCUSSION

Mean values for the riboflavin content of freshly harvested peas, snap beans, soybeans, and spinach; for the riboflavin contents of these vegetables after blanching, blanching and cooling, and blanching, cooling, and 20 hours in the freezing unit; and for percentage retentions of the processed vegetables are presented (Table 2). Mean values and standard deviations of the means are given in mg. per 100 gm. as determined, while the figures for retention are calculated on the basis of the original raw lot weights, and represent total amounts in per cent of riboflavin retained. Dark Podded Thomas Laxton and Little Marvel peas contained .192 ± .0057 and .173 ± .0024 mg. riboflavin per 100 gm., respectively; Asgrow Black Valentine snap beans grown in 1945, .128 ± .0025, and grown in 1947, .122 ± .0038; Giant Green soybeans, .267 ± .0038; and Bloomsdale Savoy Long Standing and Virginia Savoy (Blight Resistant) spinach, .212 ± .0030 and .335 ± .0059, respectively. Values for peas, snap beans, and Virginia Savoy (Blight Resistant) spinach are within the ranges of figures reported in the literature for these vegetables. However, the Giant

TABLE 2

Riboflavin Content of Four Vegetables, During Preparation for Freezing and After Freezing

Vegetable and variety	Year	Raw		After blanching		After blanching and cooling		After 20 hours in the freezing unit	
		Moisture mean and standard deviation of the means	Riboflavin mean and standard deviation of the means as determined	Riboflavin mean and standard deviation of the means as determined	Retention of riboflavin, original weight basis	Riboflavin mean and standard deviation of the means as determined	Retention of riboflavin, original weight basis	Riboflavin mean and standard deviation of the means as determined	Retention of riboflavin, original weight basis
		pct.	*mg./100 gm.*	*mg./100 gm.*	*pct.*	*mg./100 gm.*	*pct.*	*mg./100 gm.*	*pct.*
Peas									
Dark Podded Thomas Laxton	1945	81.5±.18	.192±.0057	.180±.0040	85	.166±.0036	82	.156±.0025	78
Little Marvel	1947	81.5±.11	.173±.0024	.160±.0026	87	.153±.0029	86	.160±.0024	90
Snap beans									
Asgrow Black Valentine	1945	92.6±.15	.128±.0025	.116±.0023	85	.116±.0021	88	.125±.0026	96
Asgrow Black Valentine	1947	90.7±.21	.122±.0038	.112±.0033	87	.102±.0033	85	.111±.0030	92
Soybeans									
Giant Green	1946	71.9±.42	.267±.0038	.....	....	.216±.0056	81[1]	.210±.0048	78[1]
Spinach									
Bloomsdale Savoy Long Standing	1945	93.2±.20	.212±.0030	.....	....	.164±.0027	58	.157±.0030	55
Virginia Savoy (Blight Resistant)	1945	90.3±.11	.335±.0059	.....	....	.294±.0048	69	.308±.0058	70

[1] Based on the assumption that there is no difference between weights of raw, and of blanched and cooled soybeans blanched and cooled in the pods.

Green soybeans had a higher concentration of riboflavin than Bedford *et al.* (1944 and 1945) reported for Bansei soybeans, and the Bloomsdale Savoy Long Standing spinach had less riboflavin than other workers have found in different varieties.

Dark Podded Thomas Laxton and Little Marvel peas which had been blanched, blanched and cooled, and blanched, cooled, and held 20 hours in the freezing unit retained from 78 to 90 per cent of the amounts of riboflavin originally present, while Asgrow Black Valentine snap beans retained from 85 to 96 per cent. It seems logical to postulate that the losses occurred mainly during blanching and that the ranges obtained represent the uncertainty of the method of riboflavin determination for these vegetables. Bedford *et al.* (1944 and 1945) found greater decreases in riboflavin content when peas, and in some instances when snap beans, were blanched in water than those reported here. Percentage retentions of riboflavin in Giant Green soybeans were 81 and 78 after blanching and cooling and after freezing, respectively. When spinach was processed, greater losses in riboflavin content occurred. These ranged from 30 to 45 per cent for the two varieties studied, and are comparable to the loss of 40 per cent reported for commercial quick-freezing by Gleim *et al.* (1944).

Mean values for the riboflavin contents and for percentage retentions of riboflavin after one, three, six, and nine months of freezer storage are given (Table 3). There is no indication of further losses of riboflavin in frozen peas, snap beans, soybeans, and spinach during these periods of freezer storage. Figures for riboflavin content reported by Kelly *et al.* (1944) and Bedford *et al.* (1944 and 1945) also indicate that amounts of riboflavin present in frozen vegetables do not decrease significantly during freezer storage.

In the present study, comparison of the values for percentage retentions of riboflavin (Tables 2 and 3) in Dark Podded Thomas Laxton and Little Marvel peas, indicates no consistent differences between these varieties, after preparation for freezing, holding 20 hours in the freezing unit, and freezer storage. Similarly, snap beans grown in 1945 and 1947 retained approximately the same amounts of riboflavin. Virginia Savoy (Blight Resistant) spinach had a significantly [2] higher concentration of riboflavin than Bloomsdale Savoy Long Standing spinach. With the former variety percentage retentions were always slightly higher than with the latter, significantly so after blanching and cooling, and after blanching, cooling, and holding 20 hours in the freezing unit.

Values showing effect of cooking on the riboflavin content of stored frozen peas and snap beans are presented (Table 4). After cooking, frozen Dark Podded Thomas Laxton peas which had been held in the freezer for six months retained 64 per cent of the riboflavin originally present in the

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[2] Standard deviation of the means $S\bar{X} = \sqrt{\frac{\Sigma x^2}{n(n-1)}}$

Standard error of difference between means $= \sqrt{(S\bar{X}_1)^2 + (S\bar{X}_2)^2}$

A difference is considered significant when it is equal to or greater than three times the standard error of the difference between means.

TABLE 3

Riboflavin Content of Four Frozen Vegetables, After 1, 3, 6, and 9 Months of Freezer Storage

Vegetable and variety	Year	After 1 month of freezer storage		After 3 months of freezer storage		After 6 months of freezer storage		After 9 months of freezer storage	
		Riboflavin mean and standard deviation of the means as determined	Retention of riboflavin, original weight basis	Riboflavin mean and standard deviation of the means as determined	Retention of riboflavin, original weight basis	Riboflavin mean and standard deviation of the means as determined	Retention of riboflavin, original weight basis	Riboflavin mean and standard deviation of the means as determined	Retention of riboflavin, original weight basis
Peas		*mg./100 gm.*	*pct.*	*mg./100 gm.*	*pct.*	*mg./100 gm.*	*pct.*	*mg./100 gm.*	*pct.*
Dark Podded Thomas Laxton	1945	.197±.0046[1]	94[1]	.173±.0042[1]	88[1]	.175±.0039	88	.167±.0025	83
Little Marvel	1947	.155±.0018	87	.162±.0017	91	.171±.0015	96	.159±.0020	89
Snap beans									
Asgrow Black Valentine	1945	.122±.0025	92	.117±.0022	89	.119±.0029	90	.121±.0022	90
Asgrow Black Valentine	1947	.111±.0030	90	.116±.0040	95	.101±.0030	83	.111±.0038	90
Soybeans									
Giant Green	1946	.197±.0027	74[2]	.191±.0033	72[2]	.188±.0031	70[2]	.202±.0039	76[2]
Spinach									
Bloomsdale Savoy Long Standing	1945	.165±.0058	58	.173±.0033	60	.181±.0024	63	.174±.0015[1]	60[1]
Virginia Savoy (Blight Resistant)	1945	.285±.0058	66	.280±.0028	66	.270±.0065	64	.283±.0042	66

[1] Three, instead of four, replications. [2] Based on the assumption that there is no difference between weights of raw, and of blanched and cooled soybeans blanched and cooled in the pods.

fresh, raw vegetables, while Little Marvel peas stored for nine months retained 68 per cent. The respective percentage retentions, calculated on amounts present in the frozen stored vegetables, were 73 and 76. These figures are only slightly higher than those reported by Johnston *et al.* (1943), and are similar to the 70 and 82 per cent retentions obtained by Briant *et al.* (1946) after boiling frozen peas in a steam-jacketed kettle. After cooking, frozen Asgrow Black Valentine snap beans stored for three, six, and nine months retained 77, 68, and 76 per cent, respectively, of amounts of riboflavin originally present in the fresh vegetables; and 82, 76, and 84 per cent of the amounts in the frozen stored beans. Farrell and Fellers (1942) found no loss of riboflavin when snap beans were cooked in one-fourth their weight of water. However, Phillips and Fenton (1945) reported that solidly frozen snap beans, cooked in one-sixth their weight of water, retained 86 per cent of the riboflavin content, and that percentage retention was lower if more water was used in cooking. In the present study there was no indication of greater losses of riboflavin on cooking if the vegetable had been held in freezer storage a longer time.

TABLE 4

Riboflavin Content of Cooked, Frozen Peas and Snap Beans

Vegetable and variety	Year	Treatment	Riboflavin content mean, and standard deviation of the means as determined		Retention of riboflavin, based on values for fresh raw vegetables	
			Of fresh, raw vegetables	Of cooked, stored, frozen vegetables	In cooked vegetables	In cooking water
			mg./100 gm.	*mg./100 gm.*	*pct.*	*pct.*
Peas						
Dark Podded Thomas Laxton	1945	Frozen, stored 6 months	.192±.0057	.163±.0038	64	19
Little Marvel	1947	Frozen, stored 9 months	.173±.0024	.152±.0016	68	20
Snap beans						
Asgrow Black Valentine	1945	Frozen, stored 6 months	.128±.0025	.110±.0030	68	15
Asgrow Black Valentine	1947	Frozen, stored 3 months	.122±.0038	.112±.0024	77	10
Asgrow Black Valentine	1947	Frozen, stored 9 months	.122±.0038	.107±.0031	76	12

SUMMARY

Mean values and standard deviations of the means for riboflavin contents of the raw, freshly harvested vegetables were for Dark Podded Thomas Laxton and Little Marvel peas .192 ± .0057 and .173 ± .0024 mg. riboflavin per 100 gm., respectively; for Asgrow Black Valentine snap beans grown in 1945, .128 ± .0025, and grown in 1947, .122 ± .0038; for Giant Green soybeans, .267 ± .0038; and for Bloomsdale Savoy Long Standing and Virginia Savoy (Blight Resistant) spinach, .212 ± .0030 and .335 ± .0059, respectively.

During blanching, blanching and cooling, and blanching, cooling, and holding for approximately 20 hours in the freezing unit, the four vegetables studied lost the following amounts of the original riboflavin contents: peas, 10 to 22 per cent; snap beans, four to 15 per cent; soybeans, 19 to 22 per cent; and spinach, 30 to 45 per cent. No further losses of riboflavin occurred when these frozen vegetables were held in freezer storage for one, three, six, and nine months.

After cooking, frozen peas which had been in freezer storage six and nine months retained 64 and 68 per cent of the amounts of riboflavin present in the fresh vegetables, while snap beans, which had been frozen and stored for three, six, and nine months retained 77, 68, and 76 per cent, respectively.

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STUDIES ON PUTREFACTIVE ANAEROBES AS SPOILAGE AGENTS IN CANNED FOODS

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Microbiological problems in the canning industry represent a vast field of investigation, and much research work has been carried out in recent years. These studies have included examination of the heat resistance of organisms responsible for spoilage, as well as determination of the rate of heat penetration into different products. From data thus obtained safe processing of different canned products can be established.

As test organism in these studies, P.A. 3679 has usually been adopted in the U.S.A. This particular strain, formerly considered as *Cl. sporogenes*, has been shown by Gross, Vinton, and Stumbo (1946) to be distinct from a strain of *Cl. sporogenes* (Spray). This organism has a heat resistance somewhat in excess of the recorded maximum for *Cl. botulinum*, previously used in heat resistance studies.

In the Research Laboratory of the Norwegian Canning Industry problems concerning canned food spoilage have been a subject of research for years. In the present paper a report will be given on some of the most frequently occurring spoilage organisms, spore-forming putrefactive anaerobes, isolated from spoiled canned foods. This study includes characteristics of the prevailing strains and determination of the thermal resistance of the spores.

EXPERIMENTAL PROCEDURE

For the purpose of obtaining a cross section of the bacterial flora from unsterile canned foods, a variety of canned products was included in this investigation. From sterility tests of more than 10,000 cans of different products, carried out over a spread of several years, spoilage organisms were isolated. The following marine products were investigated: fishcakes, fishballs, corned fish, mackerel, cod roe, brisling-sardines, and dressed crab. The meat products examined included: meat cakes, meat pudding, whalecakes, beef, pork, and blood pudding. Thus, representatives of the most important domestic, as well as export, products were included. It may be noted that unsterile cans, not spoiled owing to "under-sterilization" but as a result of leakage, were excluded in this investigation.

Statistics on frequency of occurrence of unsterility of the different products were established and valuable information collected, on the nature of the organisms which economically are the most important causes of spoilage in the canning industry. Thus, flat-sour-producing bacteria are, according to our experience, of the greatest importance, the putrefactive anaerobes ranging as second in order. It is a point of interest to report that the flat-sour-producing organisms were especially important in certain canned fish products. An investigation on these organisms will be treated in another

paper. Only bacteria of the putrefactive anaerobic types will be the subject of this study.

From the above mentioned canned products 46 strains of putrefactive anaerobes, representing the most typical spoilage organisms, were isolated, and subjected to a study of taxonomic characteristics. The organisms were isolated from cans which were blown after an incubation period of 10 days at 37°C.(99°F.). The contents of the cans were usually decomposed with more or less advanced putrefaction, according to the type of canned product. In many cases spoilage organisms were encountered together with aerobic or facultative aerobic bacteria belonging to the *Bacillus subtilis* group.

For the purification and further study of the putrefactive anaerobes, several transplants from the original deep meat medium into deep agar Burri tubes were necessary. Considerable difficulties were experienced in separating the aerobic contaminants from the anaerobes; thus 30 to 40 transfers from liquid to solid media were in some cases necessary before a pure anaerobic culture was obtained.

MORPHOLOGICAL AND CULTURAL CHARACTERISTICS

The purified cultures including 46 strains were examined for differential characteristics, and 38 cultures gave the following results:

Vegetative Cells: 48 hours' deep meat medium; temperature 37°C.: Rods 0.7 to 0.8 by 3.0 to 4.5 microns with rounded ends occurring singly, often in pairs.

Endo Spores: Location subterminal to terminal. Rods distinctly swollen. Size of spores: 0.8 to 1.0 by 1.0 to 1.3 microns.

Motility: Positive.

Flagella: Peritrichous.

Gram Stain: Positive.

Agar Surface Colonies: Circular, opaque.

Deep Agar Colonies: Irregular.

Blood Agar: Hemolyzed.

Gelatin: Liquefied.

Nutrient Broth: Turbid, with foul odor.

Litmus Milk: Coagulated. Litmus reduced. Peptonization after four to six days at 37°C., leaving an amber-colored liquid:

Lead-Acetate Agar: Blackened within 48 hours.

Indol: Negative.

Nitrates: Not reduced.

Coagulated Albumin: Liquefied.

Blood Serum: Liquefied.

Brain Medium: Darkened and digested. Foul odor.

Meat Medium: Reddened, later somewhat darkened and digested with foul odor.

Fermentation Reaction: Acid and gas production from dextrose, levulose, maltose. No acid from: galactose, sucrose, lactose, dextrin, inulin, glycerol, mannitol, salicin.

Optimum Temperature: 37°C.

Toxicity: Not pathogenic to young guinea pigs by feeding or injection.

Relation to Oxygen: Anaerobic. Inhibition of growth in deep agar tubes for about 1.5 cm. from the surface.

In addition to the above cultural reactions, gas analyses were carried out with gas from blown cans which had been previously inoculated with different anaerobic strains in different kinds of meat. Gas analysis showed the composition of the gas to be mostly H_2 and CO_2, with small amounts of H_2S.

Of the 38 cultures exhibiting the above cited characteristics, one culture, No. 2, differed from the others in not attacking any carbohydrates, but was culturally, as well as morphologically, alike.

The rest of the cultures, eight in all, exhibited a colony structure very different from the others, appearing as woolly colonies in deep agar and fimbriate on surface agar (cultivated anaerobically). The other characteristics corresponded, however, in detail with the first mentioned cultures.

For the classification of the cultures Bergey's Manual (1948) and Prévot's Manuel de Classification et de Détermination des Bacteries Anaérobies (1948) were used. The main characteristics corresponded for the first 38 cultures with *Cl. parasporogenes*, McIntosh, which according to Prévot, is a variety of *Cl. sporogenes*, the difference between these organisms being the colony structure. Culture No. 2, however, differed, as already reported, in lacking power to ferment carbohydrates.

The rest of the anaerobes studied were classified according to Bergey as *Cl. sporogenes*.

As for the importance of the colony structure, Reed (1945) reports from experiments with cultivation of *Cl. parasporogenes* by successive generations that a variation from *Cl. parasporogenes* smooth type of colony to the *Cl. sporogenes* rough type occurred, and suggests that the *Cl. parasporogenes* is an invalid species.

Attempts to obtain variations in the colony structure by successive generations from our strains of *Cl. parasporogenes* and *Cl. sporogenes*, respectively, failed, as the colony structure remained constant.

DETERMINATION OF SPORE RESISTANCE

As all of the anaerobes had been isolated from spoiled canned foods, it was of importance to establish the thermal resistance of the strains for the purpose of calculating safe processing for the different products packed in the Norwegian canning industry.

Heat resistance studies were carried out with nine of the cultures, of which two were *Cl. sporogenes*, the rest *Cl. parasporogenes*. In order to secure a spore crop, the cultures were inoculated in casein digest medium, and incubated at 37°C. in 500-ml. flasks in Zeizler's vacuum jars. As a standard time of incubation a period of 10 days was selected. During this time a good crop of spores was obtained. Incubation longer than this period offered no advantage. The medium was then centrifuged in order to obtain a concentrated spore suspension, which was subsequently shaken with a sterile phosphate buffer solution (pH 7.1) and recentrifuged. The final concentrated suspension served as stock suspension, and was stored at about 0°C.(32°F.). Heat resistance tests carried out with these spore stock suspensions at different time intervals, showed heat resistance as a rule to remain constant for about a year.

In making spore counts, the spore suspension was heated to 90°C. (194°F.) for 10 minutes, and viability counts made by transferring different dilutions into agar tubes after thorough shaking of the spore suspension with glass beads. The tubes were incubated at 37°C. and the appearing colonies counted. The suspension was diluted with sterile phos-

phate buffer solution of pH 7.1, and standardized to contain 100,000 spores per ml.

The heat resistance was then determined by the thermal death-time tube method of Bigelow and Esty (1920), using two-ml. amounts of spore suspension in Pyrex tubes which were sealed after filling. (Inner diameter of the tubes seven mm.) The tubes were heated in an oil bath, equipped with a motor-driven turbine stirrer and automatic temperature control.

Heat resistance was determined at three temperatures, namely, 110, 115, and 120°C.(230, 239, and 248°F.); due allowance was made for the heat penetration lag. Ten tubes with spore suspension were removed from the oil bath at each time interval and transferred to ice water. The tubes were then subcultured into deep meat medium and incubated at 37°C. in Zeizler's vacuum jars for observation of growth. The observation period lasted one month.

With the data obtained death-time curves were drawn on semi-log paper, on which temperature was plotted on the linear scale and time on the log scale. A comparison between the F and Z values of the different strains showed No. 2 to be the most resistant, having an F value of six (Z value = 18). The other strains varied somewhat in resistance, having F values below six (average Z value = 18). The curves were not straight lines. For one of the strains death-time values were obtained at seven points, which likewise gave a slightly broken curve. Stumbo (1948) calls attention to the importance of the shape of death-time curves established at temperatures above 115°C.(239°F.) and reports that at present opinion is divided as to whether straight-line curves obtained at lower temperatures may be extrapolated as straight lines for temperatures in the higher range.

The most resistant strain, No. 2, was used as test organism in the subsequent studies.

Tanner (1944) lists a number of factors which are of importance in the testing of thermal death-time. Thus, the pH of the medium in which the spores are heated, amount of fat in the medium, and concentrations of spores are of great importance. Any study on death-time values should, therefore, be carried out on the different foods in all of its variations, and the conditions should be as closely related as possible to commercial practice.

Heat resistance was determined in the following products: dressed crab, cod roe, fishballs, fishcakes, kippers, beef, blood pudding, meatballs, meatcakes, meat pudding, mutton, whalecakes, peas, and spinach. The procedure for the heat resistance determinations was identical with the foregoing experiments, the same temperatures being used. The tube method was used for products packed with brine, the spores being heated in the particular brine to be used during packing of the product, and the concentration of the spores was 100,000 per ml. For solid packs of meat as well as marine products, the can method was used, Townsend and Esty (1938), the cans having the following dimensions: 81 x 11 mm. with a volume of 27 ml. The substrate was inoculated with a concentrated spore suspension of known concentration, and incorporated in the paste by stirring in a mechanical mixer, which assured an even distribution of the

spores. This paste was packed in test cans. Each can contained about 100,000 spores. Allowances were made for the time of heat penetration into the center of the cans, according to type of product.

The cans were immediately cooled after the heating period and subsequently incubated at 37°C. The appearance of the cans was inspected and followed up during a period of one month, cans showing evidence of swelling being considered positive.

Results from the heat resistance studies showed a variation in the F value in 14 different canned products to be from four to 8.6. These results have been applied in the canning industry. By the use of lethality curves established, and heat penetration data from experiments with corresponding foods packed in various sized containers, adequate thermal processes in terms of time and retort temperature have been calculated by the graphical method for different canned foods, Kringstad, Vesterhus, and Aschehoug (1941), Vesterhus, Aschehoug, and Kringstad (1942), and Jansen, Aschehoug, and Kringstad (1943). It must, however, be mentioned that for some products adequate processes could not be used on account of the nature of the product which would be affected organoleptically as well as nutritionally by a too severe heating. For these products processes sufficient to obtain commercial sterility are applied.

DISCUSSION AND CONCLUSIONS

Literature concerning spoilage of canned foods has revealed that non-acid foods are subject to spoilage by different types of organisms. Of the spoilage agents thermophilic bacteria are of great importance, especially in certain vegetables and milk products, while for meat and marine products the mesophilic putrefactive anaerobes have been reported as most frequently occurring.

According to examination of 13 different kinds of canned foods, including marine products as well as meat and vegetables, the most important spoilage agents were flat-sour-producing bacteria. Second in order to the flat-sour organisms were the putrefactive anaerobes, of which *Cl. parasporogenes* and *Cl. sporogenes* seemed to be typical representatives. Their presence as contaminants in unsufficiently processed canned foods may be explained by the great heat resistance of the spores and their wide-spread distribution in nature. Thus, Serck-Hanssen (1937), making a study of the anaerobic flora in samples of soil from different parts of this country, reports that *Cl. sporogenes* was present in 70 per cent of the samples. It is a point of interest to call attention to the fact that *Cl. botulinum* has not been encountered in canned foods in this country, and that cases of botulism as a whole have been very rare.

Concerning the classification of the 46 cultures of the putrefactive anaerobes studied, their morphological and cultural characteristics were identical except for the colony structure, which for eight of the cultures represented a typical woolly appearance, for the rest a lenticular to irregular one. The nearest classification according to Bergey and Prévot was *Cl. sporogenes* and *Cl. parasporogenes,* respectively. One of the cultures did not attack carbohydrates, but otherwise had identical characteristics with *Cl. parasporogenes.*

Thermal resistance studies on nine of the most typical representatives of the putrefactive anaerobes showed one strain, No. 2, to be decidedly more heat resistant than the others. For comparison, the thermal resistance of Strain No. 3679, adopted for heat resistance studies in the U.S.A., may be cited. Townsend, Esty, and Baselt (1938) report this value to be F = four (Z = 16.6). In choosing this heat resistant strain as test organism for the processing studies with different kinds of canned foods, we intended to safeguard the industry against spoilage hazards. Processing studies in small test cans were carried out with 14 different canned foods.

It is generally recognized from studies on heat penetration that the concentration of spores in the medium influences the heat resistance. In the present studies 100,000 spores per test can (containing about 30 gm.) were used. In accordance with views of other investigators we are of the opinion that the concentration to be used should be as close to the natural infection as one would encounter in canning practice. As to the degree of contamination in foods handled in the canning plants, very little is known and this important point should receive further investigation.

It is apparent from results obtained that the spore resistance of Strain No. 2 varies with different kinds of products. This may be partly accounted for by the pH of the medium. Thus, whalecakes had the lowest F value of the meat products and also the lowest pH value.

Results of the processing studies, supplemented with heat penetration data, have made it possible to establish safe processing for the most important products in the canning industry.

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COMPOSITION OF A VOLATILE FRACTION OF APPLES

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Our knowledge of the identity of the odorous constituents of apples has not increased appreciably since 1920. In that year Power and Chesnut (1920) reported that the odorous constituents of several varieties of apples consisted essentially of the amyl esters of formic, acetic, and caproic acids, with a trace of the caprylate and a "considerable proportion" of acetaldehyde. Traces of methanol, ethanol, and possibly some free formic, acetic, and caproic acids also were found. Later Power and Chesnut (1922) reported the occurrence of geraniol in McIntosh apples. Ethylene was recognized by Gane (1934) as a constituent of apple emanation. Walls (1942) described the results of chemical examination of a small amount of an odorous oil obtained by adsorbing the volatiles from whole apples on calcium chloride. After hydrolysis, he obtained a dinitrobenzoate, which he tentatively identified as an amyl derivative, and an acidic fraction, in which he obtained color tests for formic and acetic acids.

Interest in the aroma constituents of apples has been revived by the development by Milleville and Eskew (1944) of a process for the recovery from apple juice of the entire volatile odorous fraction in a concentration of about 150 times that in the original juice. This product, termed "apple essence," or "volatile apple concentrate," has a fine, fragrant apple odor. Because information on apple volatiles is relatively scanty, and also because preliminary examination of the new product gave results differing widely from those of Power and Chesnut, a systematic chemical examination was carried out on the volatile apple concentrate.

Results are summarized (Table 1). These data, calculated from refractive indices, saponification equivalents, and amounts of derivatives isolated, represent a rough approximation of the composition of apple volatiles.

The first column gives the identities of the compounds; the second shows the calculated amount of each compound in the original 10.100 kg. of 150-fold volatile apple concentrate, corresponding to the 92.2 g. of apple oil distilled.

The data (Column 3, Table 1) may be converted to the original apple juice basis by dividing by 150. Since no effort was made to extract all the juice from the original apples, or to recover the volatiles from the press cake, calculation of results on the original apple basis would be somewhat misleading. It may be of interest to point out that even assuming all the odorous material from the apples to be in the juice, a concentration in the

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original apple of 0.0035 per cent is obtained. It is also noteworthy that, contrary to results of Power and Chesnut, no amyl esters were identified.

Power and Chesnut (1920) reported their yields of apple oil, from Ben Davis and a crabapple, to be 0.0007 and 0.0013 per cent, respectively. Later (1922), they reported a yield of 0.00027 per cent for McIntosh apples. (The oil was obtained from the peels, which they stated represented 12.5 per cent of the weight of the fruit.) They also described an experiment in which McIntosh apples of the same lot were peeled, quartered, and cored, and the pulp subjected to their recovery procedure. In this case they obtained a yield of 0.00123 per cent on "weight of material employed." However, they then state, "It was evident from this result that the odorous constituents of the fruit are contained most largely in the outer portion or

TABLE 1

Estimated Composition of Apple Volatiles

Component	Amount from 10,100 g. essence	Conc. in 150-fold essence
	g.	*p.p.m.*
Total	76.46	7,560
Acetaldehyde	2.70	260
Acetone	0.08	8
Caproaldehyde	0.97	90
2-Hexenal	0.64	64
Furfural	0.01	1
Methanol	2.00	200
Ethyl alcohol	54.40	5,380
Propyl alcohol	0.76	75
2-Propanol	0.23	23
Butyl alcohol	7.90	780
Isobutyl alcohol	0.20	20
2-Methylbutanol	2.80	270
Hexyl alcohol	2.40	240
Ethyl butrate	0.70	70
Ethyl caproate	0.41	40
Other ester components:		
Alcohols: Methyl, ethyl, 2-propyl, and butyl. Acids: Formic, acetic, propionic, butyric, and caproic	0.26	26

rind." Calculation shows, however, that (even assuming a one-third loss in weight in coring the apples) the pulp from a given batch of apples would yield 1.82 g. of oil, while the peel would yield only 0.698 g. On the basis of Power and Chesnut's data, the odorous constituents are more concentrated in the outer portion, but because the pulp is the greater proportion of the apple, there is more odorous material in the pulp.

The volatile apple concentrate studied in the present work, being prepared from the juice, is probably more representative of the pulp than of the skin. In pressing the apples, a hammer mill was used to break the fruit, but the particles of skin were not finely divided. The apples were pressed cold, so it is possible that relatively little material from the skin

was included in the juice. This may account in part for the wide difference in the composition of apple odorous material reported here, and that reported by Power and Chesnut.

EXPERIMENTAL PROCEDURE

Material: Apples that had been in cold storage for about two months, were sorted to eliminate unsound fruit and washed before pressing. The 10.501 kg. of essence used for this study were obtained from 1,145 kg. of McIntosh and 1,209 kg. of Stayman Winesap apples, by use of the pilot-plant recovery unit previously described by Milleville and Eskew (1944). The 150-fold concentrate was kept cold until used.

Preliminary Concentration: The essence was fractionally distilled at atmospheric pressure in three batches through a total reflux, partial take-off column.[2] During distillation, ice water was circulated through the condenser, and a solid carbon dioxide trap kept on the vent. The receiver was jacketed with ice water. Typical data are shown (Table 2).

TABLE 2

Preliminary Distillation of Volatile Apple Concentrate[1]

Fraction No.	Boiling range	Weight	Phases
	°C.	g.	
1	30-89	39.24	One
2	89-92	33.38	Two
3	92-95	47.76	Two
4	95-97	53.80	Two
5	97-98	55.44	Two
6	98-99.5	35.15	Two

[1] Charge, 4,039 g. Distillation was continued until distillate was water only.

The corresponding fractions from the three distillations were combined and salted out by saturation with anhydrous potassium carbonate.

All material thus obtained was combined to yield 95.8 g. (0.912 per cent of original concentrate) of a light-yellow oil. A small amount (0.28 milliequivalent) of volatile acid was recovered from the potassium carbonate solution.

Properties of Apple Oil: The material had a strong fragrance, not especially characteristic of apples, which on suitable dilution closely resembled the original essence. Qualitative tests for nitrogen, sulfur, and halogen were all negative. It gave a strong Schiff's test and had a saponification equivalent of 1520; $d_{24} = 0.823$; $[\alpha]_D^{25} = -0.20° \pm 0.01°$ (homogeneous); $n_D^{25} = 1.3755$.

Fractionation of Apple Oil: A Stedman-type column, 17-mm. I. D. with an 80-cm. section packed with 95 stainless steel wire screen cells, as described by John and Rehberg (1949), was used. Ice water was circulated in the condenser, and a solid carbon dioxide trap kept on the vent during distillation. Ninety-two-and-two-tenths g. of the "anhydrous" oil

[2] The column, 2.5-cm. I. D., had a 122-cm. section packed with 4-mm. glass helices. It has a HETP = 3.3 cm. at 480 ml./hr. boil-up with a heptane-methylcyclohexane mixture.

were used (equivalent to 10.100 kg. original concentrate), and nitrogen was passed in slowly during distillation. A total of 16 fractions was obtained over the range from 21°/750 mm. to 170°/3 mm. Fraction 17 consisted of the material remaining on the column after distillation; it was removed by washing the column with acetone. The data are shown (Table 3). Saponification equivalents, calculated as if the entire fraction were an ester, are also shown in the table.

TABLE 3

Fractional Distillation of Apple Oil[1]

Fraction No.	Boiling range	Pressure	Weight	n_D^{20}	Saponification equivalent
	°C.	mm.	g.		
1	21-23	750	1.67	.....	.....
1a	23-35	750	0.01	.....	.....
2	35-66	750	1.30	1.3665	750
3	66-75	750	1.84	1.3485	1,550
4	75-78.5	750	20.42	1.3620	10,520
5	78.5-79.5	750	34.45	1.3635	11,900
6	79.5-80.5	750	1.50	1.3672	1,760
7	80.5-85	750	1.77	1.3760	580
8	85-89	750	2.42	1.3938[2]	.....[3]
9	89-92	750	1.52	1.4060[2]	.....
10	92-93	750	12.41	1.3961[2]	.....
11	56-84	150	1.88	1.4060[2]	.....
12	84-90	150	1.44	1.4080	1,940
13	90-100	150	0.98	1.4104	2,460
14	100-110	150	0.73	1.4151	1,570
15	61-62	14	2.03	1.4202	3,060
16	63 to 150	14 3.0	0.31	1.4270	1,200
17[4]	170	3.0	1.93	1.4570	491
Pot residue	.....	.....	1.2	.....	Tar

[1] Reflux ratios: Fraction 1, 7:1; 2-13, 20:1; 13-16, 5:1. Boilup, 180 ml./hr. [2] n_D^{20} for upper layer. These fractions consisted of two phases. [3] See Table 4. [4] This fraction is the residue obtained from the column only.

Fractions 8 to 11 consisted of two phases, showing initial dehydration was incomplete. Each of these fractions was saturated with potassium carbonate, and the upper layer removed. Data on these upper layers are shown (Table 4).

CHEMICAL EXAMINATION OF FRACTIONS

Methods: Each of the fractions (Tables 3 and 4) was treated by appropriate methods for identification of carbonyl compounds, alcohols, and esters. General procedures followed are outlined below:

Carbonyl Compounds: The 2,4-dinitrophenylhydrazones were prepared as described by Allen (1930). The products (or the entire reaction mixture, transferred to ether and washed alcohol-free if no solid derivative was obtained) were subjected to chromatographic adsorption on a bentonite column by the method of White (1948). By this procedure, crystalline derivatives were obtained, even when the quantity present was too

small to crystallize from the reaction mixture. Derivatives were identified by mixed melting points and by analysis.

Alcohols: Portions of the fractions were treated with a 10 per cent excess of 3,5-dinitrobenzoyl chloride, in the presence of only sufficient pyridine to combine with the HCl evolved. They were boiled one minute, transferred to a distillation flask with water, and distilled until the distillate was no longer fragrant. The distillate was reserved for identification of esters, the residue cooled and filtered. The solid was treated with an excess of two per cent sodium carbonate solution, filtered, and the insoluble material crystallized from aqueous ethanol. The dinitrobenzoates were then subjected to chromatographic adsorption on silicic acid-rhodamine 6G by the method of White and Dryden (1948), and if necessary the eluted fractions fractionally crystallized. They were identified by mixed melting points and elementary analysis.

TABLE 4

Salting Out of Diphasic Distillation Fractions

Fraction No.	Oil obtained	n_D^{20}	Saponification equivalent
	g.		
8	2.02	1.3950	460
9	1.24	1.4061	540
10	7.57	1.3990	4,530
11	0.94	1.4110	770

Esters: The aqueous distillate from the alcohol procedure contained any esters originally present, together with any alcohols unreacted with the dinitrobenzoyl chloride. It was hydrolyzed by boiling for from five to 10 hours with an equal volume of 20 per cent aqueous sodium hydroxide, and the alcohols distilled off the alkaline solution through an 18-inch Vigreux column. After addition of 0.3 ml. pyridine, the distillate (from two to 10 ml.) was saturated with anhydrous potassium carbonate and without separation of the phases one ml. of benzene and about 0.5 g. 3,5-dinitrobenzoyl chloride were added. After the reaction had subsided, the reaction mixture was transferred to a separatory funnel with ether and water, washed with water, and evaporated to dryness. The residue was then adsorbed from petroleum ether on silicic acid-rhodamine 6G, for the separation of the alcohol derivatives. By comparison of the compounds found here, with those found as free alcohols, it was usually possible to ascertain which alcohols were from esters and which were free. With this procedure, it was possible to isolate and identify as little as two mg. of an alkyl dinitrobenzoate, provided it was chromatographically separable. The potassium carbonate procedure outlined above usually gave a yield of about 50 per cent of a derivative, even though the alcohol was in a 0.5 per cent aqueous solution.

The acids from esters were in all cases volatile. They were distilled off the acidified saponification solution, titrated, and subjected to partition chromatography on wet silicic acid by the procedure outlined by Ramsey

and Patterson (1945). The fractions (either filtrates or eluates) were titrated, evaporated dry, and when sufficient material was available (at least 0.02 milliequivalent), converted to the anilide. The procedure for this is of interest, in that no special micro equipment was used. The sodium salts were evaporated in a 16-x-150-mm. test tube, 0.15 ml. of thionyl chloride was added with stirring, and after heating to boiling, about five ml. of benzene added and the tube shaken. Then 0.40 ml. of aniline in about three ml. of benzene was added with shaking, the tube boiled 30 seconds, cooled, and transferred with ether (about 25 ml.) and water (about 10 ml.) to a separatory funnel, and washed with five ml. of five per cent sodium hydroxide, five ml. of five per cent hydrochloric acid, and three times with water. The upper layer was then evaporated dry on a steam bath in a current of air. The product was crystallized by dis-

TABLE 5

Alcohols and Carbonyl Compounds Isolated as Derivatives

Fraction No.	Compounds isolated as derivatives
Cold trap	Acetaldehyde
1	Acetaldehyde
2	Acetaldehyde, acetone, methanol
3	Acetaldehyde, acetone, methanol, ethyl alcohol
4	Acetaldehyde, acetone, ethyl alcohol
5	Ethyl alcohol
6	Caproaldehyde, ethyl alcohol
7	Caproaldehyde, ethyl alcohol, 2-propanol
8	Caproaldehyde, 2-hexenal, ethyl alcohol, propyl alcohol, isobutyl alcohol
9	Caproaldehyde, 2-hexenal, ethyl alcohol, propyl alcohol
10	2-Hexenal, butyl alcohol
11	2-Hexenal, butyl alcohol, d-2-methyl-1-butanol
12	2-Hexenal, d-2-methyl-1-butanol
13	2-Hexenal, furfural, d-2-methyl-1-butanol
14	d-2-methyl-1-butanol
15	2-Hexenal, hexyl alcohol
16	Hexyl alcohol
17	Hexyl alcohol

solving it in about three ml. of petroleum ether [b. p. 60 to 67°C.(140 to 153°F.)] and allowing it to evaporate to dryness, either at room temperature or in an ice bath. The crystalline product was identified by melting point and mixed melting point, and by comparison of its X-ray powder diffraction pattern with those published by Matthews and Michell (1946). Only rarely was it necessary to treat the product with activated carbon. The order of washes of the ether solution (alkali, then acid) was the reverse of that generally used and produced a much purer product.

Constituents of the Fractions: Compounds isolated from the various fractions as derivatives are shown (Table 5). Since the same compound was usually found in several adjoining fractions, in most cases only one isolation product was quantitatively analyzed; the rest were identified by melting points and mixed melting points.

CARBONYL COMPOUNDS

Analytical data on the carbonyl compounds isolated from the apple essence are given (Table 6). Of these compounds, acetaldehyde is present in the largest quantity. Also of interest is 2-hexenal, since it has been obtained by steam distillation of the leaves of a large number of plant species. Nye and Spoehr (1943) state that in leaves it is probably an artifact, possibly being formed enzymatically when ruptured leaf cells are exposed to oxygen. Takei, Sakato, Ono, and Kuroiwa (1933 and 1938) hold it in part responsible for the "green" odor of cut grass, and believe that 2-hexenal and the corresponding alcohol are responsible for the aroma of tea. 2-Hexenal DNPH has been reported by Takei *et al.* (1938) to melt at 144°C.(291°F.) and by Tsujimura (1938) at 196°C.(385°F.). Its semicarbazone has been reported by Takei *et al.* (1938) to melt at 173°C. (343°F.); by Delaby and Guillot-Allegre (1933) to melt at 175 to 176°C. (347 to 349°F.); and by Prevost (1944) at 179°C.(354°F.). The boiling point and refractive index are given by Prevost (1944) as $B_{760} = 146°$, $n_D^{17} = 1.4480$; by Delaby and Guillot-Allegre (1933) as B. P. 150°, $n_D^{21} = 1.4470$.

TABLE 6

Volatile Carbonyl Compounds From Apples

Fraction No.	Compound	Dinitrophenylhydrazone			
		MP	Mixed MP	Analyses	
				Calcd.	Found
		°C.	°C.	pct. N	pct. N
1	Acetaldehyde	156-157	.....	24.95	25.05
2	Acetone	123.5-124.5	125-126	23.50	23.27
8	Caproaldehyde	107-108	107-108	20.00	20.46
10, 11	2-Hexenal[1]	146-146.5	146-147	20.12	20.27
13	Furfural	229-231	.....	.....	.....

[1] See text.

For reference purposes, a hexenal was prepared in poor yield by hydrogenation of 2,4-hexadienal [3] at two to three atmospheres' pressure with Raney nickel. The fraction boiling at 145 to 147°C.(293 to 297°F.), $n_D^{25} = 1.4412$), yielded a DNPH melting at 141.5°C.(287°F.); chromatography and recrystallization raised this to 146.5 to 147°C.(295 to 297°F.). *Analysis:* Calc. for $C_{12}H_{14}N_4O_4$: 51.80 per cent C, 5.04 per cent H, and 20.12 per cent N. Found: 51.75 per cent C, 4.79 per cent H, and 20.20 per cent N. The semicarbazone melted at 174°C.(345°F.).

A sample of the fraction of the synthetic preparation, which boiled at 145 to 147°C.(293 to 297°F.), was oxidized with hot chromic acid solution. Volatile acids were separated by partition chromatography; butyric acid predominated. Its anilide was prepared, and its melting point was 92.5 to 94°C.(199 to 201°F.). When mixed with butyranilide, the melting point was 92.5 to 94°C. This located the double bond in the α,β-position in the aldehyde.

[3] The 2,4-hexadienal was kindly supplied by Carbide and Carbon Chemicals Company.

The melting point of a mixture of the DNPH from apples with the synthetic hexenal DNPH was 146 to 147°C.; hence the apple aldehyde was 2-hexenal.

ALCOHOLS

Data on identification of the free alcohols from apple volatiles are summarized (Table 7). Assuming all the optical rotation of the original oil to be due to d-2-methylbutanol, it may be calculated that 3.1 g. were present in the sample examined. The corresponding value (from Table 1) by isolation is 2.8 g.

TABLE 7

Identification of Volatile Alcohols From Apples

Fraction No.	Compound	3,5-dinitrobenzoate					
		MP	Mixed MP	Analyses			
				Calculated		Found	
		°C.	°C.	pct. C	pct. H	pct. C	pct. H
2	Methanol	106-107	107-108	42.50	2.67	42.47	2.74
5	Ethanol	91-92	92	45.00	3.33	45.00	3.58
7	2-propanol	98.5-103	111	47.10	3.94	46.93	3.88
8	Isobutanol	77-79	79-83	10.45[3]		10.62[3]	
9	d-2-methylbutanol	81.5-82.5[1]	82-84[2]	51.10	4.90	51.09	5.04
10	Butanol	61.5-63	61.5-63	49.25	4.48	49.36	4.67
16	Hexanol	57-58	57-58	52.75	5.40	52.76	5.30

[1] Derivative had $[\alpha]_D^{25} = +4.4°$ (4.8 per cent in acetone). [2] See White and Ratchford (1949).
[3] Per cent nitrogen.

ESTERS

No esters, as such, were isolated. Four ester alcohols and five acids from esters were identified. Since, after saponification, most distillation fractions examined for esters contained at least two alcohols and five acids, the question of which alcohol and which acid formed the ester is left unanswered.

The procedure outlined under "Esters" was applied to all fractions with saponification equivalents of about 2,000 or below, provided material was available. Obviously, where the esters were mixed with much larger quantities of various alcohols, there was occasionally doubt as to which alcohol was from the hydrolyzed ester and which occurred free. Semi-quantitative data on proportions of the various alcohols before and after saponification, obtained from the weights of derivatives, were used when necessary to identify the ester alcohol. Amounts of volatile acids as determined by titration after distillation were in agreement with amounts of total acids as calculated from the determination of saponification equivalent; thus all acids produced from the esters were volatile.

Results obtained are summarized (Tables 8 and 9). Ethyl esters predominated. Data are included (Table 9) which show the amount of each acid recovered from the partition column as per cent of the original sample taken for analysis. This serves to indicate the relative occurrence of the various esters.

Thus, it is evident that although positive identifications of several alcohol and acid components were made, actually no esters were positively and unequivocally identified. The ester alcohols present were methanol, ethyl,

TABLE 8

Characterization of Alcohol Part of Esters as Dinitrobenzoates[1]

Fraction No.	Compound	MP	Mixed MP
		°C.	°C.
3	Methyl	103-104.5	103-105
	Ethyl	90-92	91.5-93
8	Ethyl	92-92.5	92-93
	2-propyl	83-90	109-116
9	Ethyl	91-92	91.5-92.5
12	Ethyl	89-91	90-93
	Butyl	60-62	60-62.5
14	Ethyl	88-92	.....
	Butyl	54-64	.....
17	Ethyl	91.5-92	91.5-92.5
	Butyl	51-53	51-64

[1] Small quantities generally obtained precluded microanalyses.

TABLE 9

Characterization of Acid Parts of Esters as Anilides

Fraction No.	Acid	Amount in fraction	Identification Method		
			MP	Mix MP	Other
		pct.	°C.	°C.	
3	Acetic	0.36	.....	.....	Position[1]
	Propionic	0.45	.....	.....	X-ray[2]
8	Formic	0.12	49	.....	.....
	Acetic or propionic	(0.4)	102	.....	.....
	Butyric	6.7	93.5-94.0	94-94.5	X-ray
	Caproic	1.9	95.5-96.0	.....	X-ray
9	Formic	0.67	.....	.....	Position
	Possibly acetic	0.15	.....	.....	Position
	Possibly propionic	0.21	.....	.....	Position
	Butyric	6.4	93	94	X-ray
	Mixture	1.5	.....	.....	X-ray
	Caproic	4.1	94	94.5	X-ray
12	Formic	0.10	.....	.....	Position
	Acetic	0.41	.....	.....	X-ray[3]
	Caproic	1.8	.....	.....	X-ray
14	Formic	0.19	.....	.....	Position
	Acetic	0.49	112-115	112-114	.....
	Propionic	0.15	.....	.....	Position
	Butyric	0.69	89-90	90.5-93	.....
17	Acetic	0.73	.....	.....	X-ray
	Propionic	0.45	.....	.....	X-ray
	Caproic	2.4	.....	.....	X-ray

[1] "Position" refers to probable identity of compound by its position on the partition chromatographic column, in relation to identified acids. [2] Refers to identification by x-ray powder diffraction pattern. [3] Single crystal x-ray diffraction pattern.

2-propyl, and butyl alcohols; the acids from esters included formic, acetic, propionic, butyric, and caproic. Presence of ethyl butyrate and ethyl caproate in one fraction was established (Fraction 9). Ethyl formate, acetate, and propionate were also probably present.

SUMMARY

The chemical composition of the aroma of apples has been investigated. The principal components, together with the relative amounts of each class, are alcohols (92 per cent): methanol, ethyl alcohol, propyl alcohol, 2-propanol, butyl alcohol, isobutyl alcohol, d-2-methyl-1-butanol, and hexyl alcohol; carbonyl compounds (six per cent): acetaldehyde, acetone, caproaldehyde, and 2-hexenal; esters (two per cent): ethyl butyrate and ethyl caproate. Methanol, ethyl alcohol, 2-propanol, butyl alcohol, and formic, acetic, propionic, butyric, and caproic acids were identified as components of other esters. These compounds are present in the original apple juice at a total concentration of approximately 50 parts per million.

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BROWNING OF ASCORBIC ACID IN PURE SOLUTIONS[1]

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This study of the browning of heated solutions of ascorbic and citric acids had its origin in the larger study of the nonenzymatic browning of foodstuffs, and more specifically in the browning of citrus powders and concentrates. A relationship between darkening and loss of ascorbic acid in citrus products has been noted by several investigators: Hamburger and Joslyn (1941), Joslyn, Marsh, and Morgan (1934), Joslyn and Marsh (1935), Loeffler (1941), Moore, Wiederhold, and Atkins (1944), and Stevens, Shipston, and Wilson (1941).

Also, observations of the browning of solutions of ascorbic acid and its oxidation product, dehydroascorbic acid, have been reported: Borsook, Davenport, Jeffreys, and Warner (1937), Ghosh and Rakshit (1938), Herbert, Hirst, Percival, Reynolds, and Smith (1933), Hirst and Zilva (1933), Svirbely and Szent-Gyorgyi (1932), and Szent-Gyorgyi (1928). Rosenfeld (1943) found that a yellow-colored substance appeared regularly in the course of the anaerobic spontaneous transformation of dehydroascorbic acid and postulated this compound to be triketogulonic acid lactone.

Fearon and Kawerau (1943) reported formation of a green pigment on boiling an acidic solution at pH 3.4 to 4.5 of dehydroascorbic acid, and the spontaneous anaerobic formation of a red pigment in unheated solutions of dehydroascorbic acid. They suggested that furfural derivatives were being formed.

Yourga, Esselen, and Fellers (1944) found that solutions of d-isoascorbic acid, l-ascorbic acid, and sodium d-isoascorbate developed an increasingly darker yellow-brown color during oxidation. Seaver and Kertesz (1946) reported formation of a yellow color in an ascorbic acid solution at pH 4.3, heated at 98°C.(208°F.) for from one to four hours.

The present investigation was designed to study some of the changes occurring during browning, when powder mixtures or solutions of ascorbic acid and citric acid are heated, and to determine what factors are involved.

A. EXPERIMENTAL. CITRIC ACID

(1) *Effect of Water of Crystallization:* It was shown by Isaac (1943) that the water of crystallization of citric acid which had been added to

[1] Material in this paper was taken from a thesis submitted by M. P. Lamden to the Graduate School of the Massachusetts Institute of Technology, in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Food Technology, 1947.

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artificial citrus powders increased their darkening. Proctor and Sluder (1942) have observed that removal of the last few percentages of moisture from dehydrated citrus products retarded browning during storage. These observations indicate that the presence of water of crystallization may be a cause of browning of mixtures of citric acid and ascorbic acid, both of which are present in citrus fruits.

Mixtures of ascorbic and citric acids were compounded in approximately the same ratio as found in dehydrated lemon juice, as follows:

FORMULA 1

Crystalline citric acid (contains one molecule of water of crystallization)....25.00 gm.
Crystalline ascorbic acid..... 0.15 gm.

FORMULA 2

Anhydrous citric acid.....23.00 gm.
Crystalline ascorbic acid..... 0.15 gm.

Each mixture was finely pulverized by mortar and pestle, filled into two-ounce screw-cap bottles, then stored at 48.9°C.(120°F.). After one week the samples of Formula 1 (containing the hydrated citric acid) had browned considerably and had developed a strong caramel-like odor; samples of Formula 2 (containing anhydrous citric acid) had a very faint yellow-brown color and only a slight caramel-like odor.

The effect of the water of crystallization of citric acid on browning was also shown indirectly in the following manner: Samples of Formula 1 (containing hydrated citric acid) were placed in glass jars. Similar glass jars, containing granular anhydrous calcium chloride retained by cheesecloth, were inverted and sealed to the first jars with cellulose tape. After one week's storage at 48.9°C. the samples were examined. The surface of each ascorbic-citric acid mixture was white and dry. Beneath the surface, the samples had become a yellow-brown, which increased in intensity as the distance from the surface increased. Even the darkest portions, however, were considerably lighter than samples of Formula 1, which were stored in the bottles without anhydrous calcium chloride.

It may be concluded that the calcium chloride removed the water of crystallization of the citric acid more completely from the surface of the mixture than from the lower layers, and that remaining water promoted the browning reaction.

(2) *Effect of Citric Acid Concentration on Color Formation and Ascorbic Acid Loss:* It has been reported that loss in ascorbic acid, Stevens *et al.* (1941), and development of color, Hall (1927), increases as the concentration of solids in citrus concentrates is increased. Citric acid, along with other ingredients, becomes more concentrated as citrus juice is dehydrated. Furthermore, Matthew (1928) has reported that an increase in acidity of orange juice accelerated darkening. It was logical, therefore, to measure the effect of citric acid concentration on color formation and on the breakdown of ascorbic acid while a mixture of ascorbic acid and citric acid was heated. An aqueous solution was used, rather than a powder mixture, because samples could be prepared more precisely and analyzed more readily. Also, the browning reaction would occur faster in aqueous solutions of the acids.

Citric acid was dissolved in distilled water to give the following concentrations: one, 10, 20, 30, and 50 per cent. To nine ml. of each of the above solutions was added one ml. of an ascorbic acid solution containing 240 mg. ascorbic acid per ml. After mixing, the solutions were heated in tubes fitted with cold finger condensers in a boiling water bath for three hours, then quickly cooled in ice water.

Solutions were analyzed for ascorbic acid content by the visual titration method, Miller (1942), and the optical density determined against distilled water in a photoelectric colorimeter, using a filter with maximum transmission at 410 mμ. Experimental data are shown (Table 1).

A definite increase in color formation and in ascorbic acid loss was noted (Table 1) with each increase in citric acid concentration.

TABLE 1

Optical Density and Ascorbic Acid Content of Solutions Containing 2.4 Per Cent Ascorbic Acid and .9, 9, 18, 27, and 45 Per Cent Citric Acid After Heating at 100°C. Three Hours[1]

Citric acid concentration	Color measured as optical density	Ascorbic acid	Loss in ascorbic acid
pct.	*at 410 mμ.*	*mg./10 ml.*	*pct.*
0.9	.0969	225.0	6.25
9.0	.1612	217.5	9.37
18.0	.2328	210.0	12.5
27.0	.2990	202.5	15.6
45.0	.5850	195.0	18.75

[1] Initial ascorbic acid concentration, 240 mg. per 10 ml.

A few simple experiments showed that browning of ascorbic acid could occur in the presence of organic acids other than citric acid. Malic, tartaric, and oxalic acids all caused color formation when heated with ascorbic acid at 100°C.(212°F.).

B. EFFECT OF AIR ON BROWNING AND ON ASCORBIC ACID LOSS

It has been shown that exposure to air caused an increase in the darkening of orange juice, Joslyn *et al.* (1934) and Matthew (1928). However, it is also reported that removal of molecular oxygen did not prevent darkening or loss of ascorbic acid in orange juice, Joslyn and Marsh (1935) and Loeffler (1941). In the darkening of orange concentrates, oxidation has been considered a minor accessory factor, Hall (1927). In an attempt to establish the effect of oxygen on darkening of citrus products, experiments were carried out on ascorbic acid-citric acid solutions.

(1) *Color Development and Ascorbic Acid Loss on Heating Solutions With and Without Vacuum:* Nitrogen was swept through a 50 per cent solution of citric acid, to which was added enough ascorbic acid to give a final concentration of 25 mg./ml. Then five ml. of this solution were pipetted into a series of Thunberg tubes, which were then evacuated to a pressure of 75 μ. of mercury (on a MacCleod Gauge). Half of the tubes were then opened to the atmosphere at room temperature and shaken for a few minutes to facilitate absorption of air. All were placed in a water bath at 100°C. Color developed in the evacuated tubes as well as in those

open to the atmosphere. Color in both started as a light-yellow which developed a reddish tinge that became more pronounced with time. At the end of two hours the solutions were tested for optical density at 410 mμ. and for ascorbic acid content by the visual titration method.

A summary of results of this experiment is shown (Table 2).

TABLE 2

Optical Density and Ascorbic Acid Content of Solutions Containing 25 mg./ml. Ascorbic Acid With and Without Deaeration Before Heating Two Hours at 100°C.

Solution	Optical density	Ascorbic acid	Ascorbic acid loss
	Filter max. 410 mμ.	*mg./ml.*	*pct.*
Control	.0605	24.38	.....
Under vacuum	.940	20.25	19.96 pct.
Atmospheric	.949	20.25	19.96 pct.

Loss of ascorbic acid was the same in tubes under vacuum as in tubes exposed to the atmosphere. Color development was the same within experimental error.

In another experiment on solutions of the same composition, prepared under nitrogen, bubbling of nitrogen through the solutions being heated did not prevent color formation. Apparently, oxygen is not necessary for color formation and for destruction of ascorbic acid, when a strong citric acid solution containing ascorbic acid is heated.

C. EFFECT OF SULFUR DIOXIDE

Matthew (1928), Joslyn *et al.* (1934), and Hamburger and Joslyn (1941) have shown that sulfur dioxide prevented or retarded darkening in orange juice. Hamburger and Joslyn (1941) were of the opinion that sulfur dioxide prevented this darkening of orange juice, because of its antioxidant action on ascorbic acid or on its decomposition products. The following experiment was carried out to determine the effect of sulfur dioxide on color development in an ascorbic acid-citric acid solution:

To each of four tubes containing 10 ml. of a 50 per cent citric acid solution was added one ml. of an ascorbic acid solution which contained approximately 250 mg. ascorbic acid. The tubes and a citric acid control were heated in a water bath at 100°C. one hour. Sulfur dioxide was bubbled through two of these tubes.

The citric acid control and the solutions that were swept with sulfur dioxide developed no color, whereas the citric acid-ascorbic acid solution without sulfur dioxide became yellow. Since the previous experiment indicated that oxygen was not necessary for color formation under conditions involved, it is unlikely that the color-inhibiting action of sulfur dioxide is an antioxidant action.

D. EFFECT OF INITIAL ASCORBIC ACID CONCENTRATION

Relationship between color formation and initial ascorbic acid content in a simple acid solution has not been demonstrated. However, Rosenfeld (1943) incubated [37°C.(99°F.)] anaerobically a dehydroascorbic acid

solution at pH 7 and showed that a straight-line relationship existed between initial dehydroascorbic acid content and development of a yellow compound.

Solutions were prepared to contain 10 ml. of a 50 per cent citric acid solution plus one ml. of a 50 per cent citric acid solution containing from zero to 100 mg. ascorbic acid. The solutions were placed in tubes containing finger-like condensers, and heated in a water bath at 100°C. three hours. They were then cooled and the optical density determined in a photoelectric colorimeter, using a filter transmitting maximally at 410 mμ.

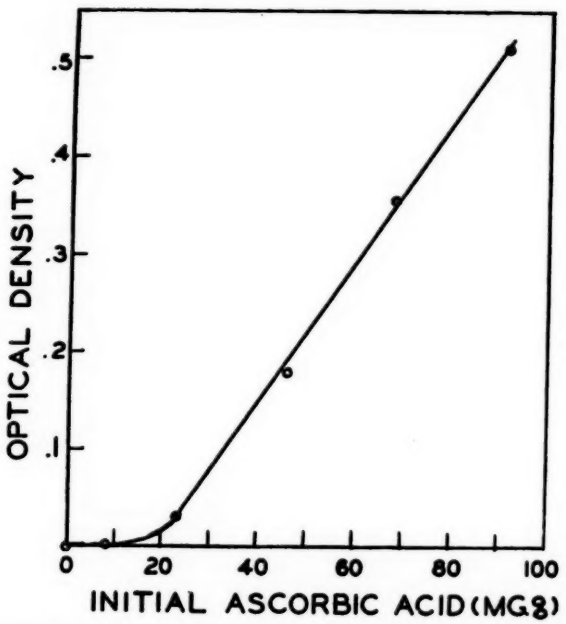

FIG. 1. Effect of initial ascorbic acid concentration on color formation. Ascorbic acid is dissolved in 50 per cent citric acid solution. Temperature: 100°C. Time: three hours. Color measured as optical density using filter with maximum absorption at 410 mμ.

Results (Fig. 1) show a straight-line relationship existed between initial ascorbic acid content and color formation, except in the very low concentrations. Thus, color formation appears to be a function of the initial ascorbic acid content.

E. CHANGES OCCURRING DURING BROWNING OF HEATED MIXTURES AND SOLUTIONS OF ASCORBIC ACID AND CITRIC ACID

(1) *Production of Furfural:* Cox, Hirst, and Reynolds (1932), Roe (1936), and Woker and Antiner (1937) have described the production of furfural by boiling ascorbic acid in strong mineral acid. Some experiments were carried out to determine whether furfural was produced from

ascorbic acid in the presence of citric acid, instead of strong mineral acids.

A solution made up of five ml. of 50 per cent citric acid containing 0.5 gm. ascorbic acid was boiled gently in a test tube. The aniline acetate test for furfural, Mulliken and Huntress (1937), simultaneously performed, indicated furfural formation. A positive cherry-red test for furfural was obtained.

When this test was repeated on 0.5 gm. ascorbic acid oxidized by iodine to dehydroascorbic acid, the test was negative for furfural. Roe (1936) found that when dehydroascorbic acid was boiled with strong hydrochloric acid, no furfural was obtained, either. This is in keeping with the postulate of Woker and Antiner (1937) that hydroxyfurfural is produced on boiling dehydroascorbic acid with strong hydrochloric acid. Cross, Bevan, and Heiberg (1899) mentioned that hydroxyfurfural gave a negative aniline acetate test and stated further that hydroxyfurfural did not distill with steam. That may explain why Fearon and Kawerau (1943) failed to obtain "furfural" by distillation of a colored solution obtained by boiling dehydroascorbic acid at pH 4 for a few minutes.

F. CARBON DIOXIDE EVOLUTION, OXYGEN UPTAKE, AND ASCORBIC ACID BREAKDOWN

It is known that carbon dioxide is produced by heating ascorbic acid with mineral acid. Wilson (1928) and Loeffler (1941) observed the evolution of CO_2 from orange juice on storage. Fearon and Kawerau (1943) noted the evolution of carbon dioxide from a boiling solution of dehydroascorbic acid at pH 4.

TABLE 3

Carbon Dioxide Evolution and Oxygen Absorption by Solutions Containing 2.5 Per Cent Ascorbic and 50 Per Cent Citric Acid During Heating at 60°C. Five Hours

Run	Ascorbic acid		CO_2 evolved in 5 hours	O_2 absorbed in 5 hours
	Reduced	Total		
	mg./5 ml.	*mg./5 ml.*	*mg.*	*mg.*
Control	127.5	128.7	.....	.....
Run No. 1	120.0	121.2	1.107	.616
Run No. 2	120.0	120.0	1.085	.648
Average	120.0	120.6	1.096	.632

Using Barcroft differential manometers, with Warburg side-arm vessels agitated as units in a constant temperature bath, an experiment was carried out to measure carbon dioxide evolution while 128.7 mg. ascorbic acid, dissolved in five ml. of 50 per cent citric acid, were heated at 60°C. (140°F.). At the same time, oxygen uptake and ascorbic acid loss were measured. Results from two five-hour runs are shown (Table 3).

It was noted there was practically a straight-line relationship between carbon dioxide evolution and time; also between oxygen uptake and time. According to the equation for the breakdown of ascorbic acid when heated in the presence of strong hydrochloric acid, suggested by Woker and Antiner (1937), assuming complete conversion of the ascorbic acid destroyed, 25 per cent should appear as carbon dioxide. The quantity of carbon diox-

ide evolved in these runs was only 13.5 per cent of the destroyed ascorbic acid. Evolution of less than the theoretical quantity of carbon dioxide may indicate that a portion of the ascorbic acid was not completely converted and that intermediate products were formed, instead.

The role played by the absorbed oxygen is still a subject of much postulation. It might oxidize ascorbic acid to dehydroascorbic acid; however, since the data did not show a significant formation of dehydroascorbic acid, it may be concluded that this acid either was not formed or was rapidly converted into another compound, possibly diketogulonic acid. Assuming conversion of the ascorbic acid to furfural, the absorbed oxygen might preferentially oxidize the furfural to hydroxyfurfural.

G. INVESTIGATION OF POSSIBLE LOSS OF CITRIC ACID

It was desirable to know whether citric acid functioned only as an acid catalyst in the browning of ascorbic acid, or underwent chemical change in the reaction.

The colorimetric pentabromacetone method of Pucher, Sherman, and Vickery (1936), for the determination of citric acid, was used to determine whether there was a change in the citric acid content during the browning of an ascorbic acid-citric acid mixture containing 25 parts of citric acid and one part of ascorbic acid. Test samples containing 0.250 gm. of mixture were heated in closed test tubes in a water bath at 100°C. two and one-half hours, during which time browning occurred.

Citric acid content of the heated samples and unheated controls is shown (Table 4). Results indicate there was no loss or breakdown of citric acid during browning of an ascorbic acid-citric acid mixture, for the differences are within the experimental error (± five per cent) of the analysis.

TABLE 4

Citric Acid Content of Solutions Containing 25 Parts Citric Acid and One Part Ascorbic Acid, Before and After Heating at 100°C. Two and One-Half Hours

Sample	Total citric acid in mixture	
	gm.	*gm.*
Before heating A	.235	.....
Before heating B	.225	.230
After heating A	.240	.....
After heating B	.235	.238

H. COLOR DEVELOPMENT AND ASCORBIC ACID LOSS WITH TIME

In following the change in the ascorbic acid content during color formation, data were obtained which could be used to study the reaction by which ascorbic acid decomposed with resultant color formation.

A 50 per cent citric acid solution containing about 50 mg. ascorbic acid per ml. was prepared, and 10 ml. were placed in each of a number of tubes with finger-like condensers. These tubes were then placed in a water bath at 100°C. At intervals a tube was removed, cooled in ice water, and its optical density and ascorbic acid content measured. Results obtained are shown (Table 5).

When the log of the ascorbic acid concentration is plotted against time (Fig. 2), a linear relationship is obtained. This suggests it is a first-order or monomolecular reaction.

TABLE 5

Changes in Optical Density and Ascorbic Acid Content of Solutions Containing 50 Per Cent Citric Acid and Five Per Cent Ascorbic Acid, During Heating at 100°C.

Time	Optical density	Ascorbic acid
min.	*at 410 mμ.*	*mg./ml.*
0	.000	48.25
10	.000	48.25
20	.018	47.40
30	.065	47.05
50	.180	45.75
75	.398	44.10
105	.629	43.00

GENERAL DISCUSSION

Citrus fruits have a number of natural components which may contribute to darkening of citrus concentrates and dehydrated citrus powders. Two of these components, ascorbic acid and citric acid, by themselves in a powder mixture, can undergo color formation at high storage temperatures, as has been shown here. Pure solutions of ascorbic acids and citric acids may be used cautiously to explain some results which others have obtained on citrus products. They may also contribute to a better understanding of the reactions involved in the nonenzymatic browning of citrus products.

It was observed that the water of crystallization of citric acid promoted the browning of a powder mixture of ascorbic and citric acids at 49°C.(120°F.), and removal of this water of crystallization almost completely eliminated color formation. This parallels the finding that removal of the last few percentages of water from dehydrated citrus juices considerably retards darkening during storage.

This finding also suggests the difficulty that may arise when ascorbic acid used in frozen fruit preservation is premixed with crystalline or powdered acids containing water of crystallization. It further suggests protection of water-free mixtures from moisture.

Increasing the acidity of ascorbic acid solutions to higher levels with citric acid, followed by heating, resulted in greater darkening of the solutions. Also, increasing the ascorbic acid content of an ascorbic acid-citric acid solution resulted in greater darkening. On the basis of these findings it is not surprising that darkening of concentrated citrus products occurs more readily and to a greater extent than in nonconcentrated products, since the concentrations of ascorbic acid and citric acid are considerably increased.

It was found that oxygen is apparently not a factor in color formation or ascorbic acid destruction, when highly acidic solutions of ascorbic acid and citric acid are heated. This finding may be related to the observation that vacuum-packing did not seem to improve the stability of dehydrated lemon powder on storage, Proctor and Sluder (1943).

It is noteworthy that sulfur dioxide, which prevents browning of citrus juices and powders, and the browning reaction in foods in general, also was demonstrated to prevent formation of color when present when highly acidic ascorbic acid solutions were heated. Perhaps the formation of a sulfite addition compound is linked with inhibition of browning.

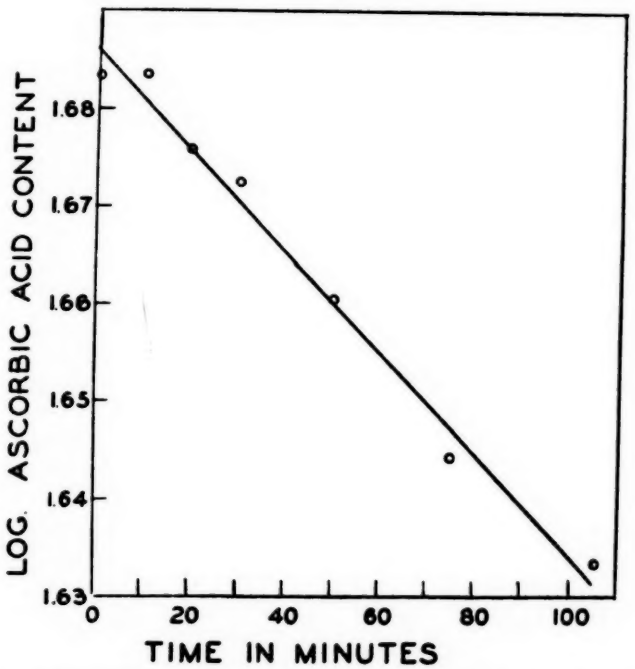

FIG. 2. Relationship between the logarithm of the ascorbic acid content and time. Ascorbic acid concentration: initially, 48.25 mg./ml. in 50 per cent citric acid solution. Temperature: 100°C.

Since furfural or furfural derivatives can form when highly acidic ascorbic acid solutions are heated, it is reasonable to expect that furfural compounds will form when citrus concentrates and powders are kept at high storage temperatures for long periods of time. In these citrus products, however, the possibility of color formation may be greater than in pure ascorbic acid-citric acid mixtures, due to the great variety of chemical compounds present that may condense with furfural or furfural-related compounds to form undesirable colored derivatives.

This paper has been concerned largely with browning in highly acidic ascorbic acid solutions, generally at a pH below 2.5. The browning of ascorbic acid solutions which are less acid are discussed elsewhere, Lamden and Harris (in preparation).

CONCLUSIONS

Model mixtures containing pure ascorbic acid and citric acid were used to study the effect of heating on development of color and on loss of ascorbic acid.

The water of crystallization of citric acid ($C_6H_8O_7 \cdot H_2O$) promoted browning of a powdered mixture of ascorbic acid and citric acids at 49°C.

Ascorbic acid-citric acid solutions containing increasing amounts of citric acid, and heated three hours at 100°C., showed an increased optical density (at 410 mμ.) and a decreased ascorbic acid content with increasing concentration of the citric acid.

Malic, tartaric, and oxalic acids also caused color formation when heated with ascorbic acid at 100°C.

Neither color formation nor loss in ascorbic acid depended on the presence of oxygen, during heating of highly acidic solutions of ascorbic acid.

Sulfur dioxide prevented formation of color in ascorbic acid solutions. Sulfur dioxide probably does not function as an antioxidant in this reaction.

Color formation was demonstrated to be a function of the initial ascorbic acid content in highly acidic ascorbic acid solutions heated at 100°C.

Furfural was formed when an ascorbic-citric acid solution was boiled. It was not formed when a dehydroascorbic acid solution was boiled.

Oxygen was consumed and carbon dioxide was evolved at a linear rate when an ascorbic-citric acid solution was heated at 60°C. Approximately half the carbon dioxide theoretically obtainable from the ascorbic acid destroyed was accounted for. The remainder may have been present as an ascorbic acid transformation product or products not yet decarboxylated.

There was no measurable decomposition of citric acid during browning of a heated ascorbic-citric acid mixture.

Rate of loss of ascorbic acid in highly acidic solutions indicated the reaction was monomolecular.

The bearing of these results upon the browning reaction noted in dehydrated citrus products is discussed.

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